Bonobos Cooperate Like Humans | Our Favorite Books of 2023

Science News

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ DECEMBER 16, 2023 & DECEMBER 30, 2023



Hot as BLAZES

In 2023, the world roasted under record-breaking heat

VOL. 204 | NO. 10

ScienceNews



16

2023 Year in Review

News



4



6

Departments

COVER Climate change and El Niño cranked up temperatures this year. *Korakrich Suntornnites/ iStock/Getty Images Plus, T. Tibbitts*

FROM TOP: BRANDON BELL/GETTY IMAGES NEWS; GIANT MAGELLAN TELESCOPE/GMTO CORPORATION; M. SURBECK/KOKOLOPORI BONOBO RESEARCH PROJECT



The march of progress takes many detours

If the name of your magazine is *Science News*, you cover the news of science. That may sound like a simple assignment. But the march of science follows no straight path. Instead, there are shaky starts, dashed hopes and reverses along the way.

In this year-end issue, we revisit the big discoveries of 2023, as well as some that might be big news if the evidence holds up. There's plenty to choose from; each year we spend weeks debating the merits of candidates for our short list.

Among our picks: The ascension of ChatGPT and other generative AI chatbots, which were used for an ever-growing list of tasks, including answering questions, assisting programmers in writing code and helping with — or doing — homework (SN: 4/8/23, *p.* 24). But these precocious virtual assistants are still in their toddler phase, displaying humanlike language skills while also mangling sentences and making up citations (Page 20).

One very big claim this year — creating the world's first room-temperature superconductor that works at relatively low pressure — would have been revolutionary had it held up. The claim collapsed amid accusations of data manipulation and failures to replicate, raising fears that the scandal could chill future superconductor research. But physicists remain determined to solve the challenge, which could transform computing, energy transmission and other technologies (Page 22).

Each year, we also highlight discoveries that are "big if true," fascinating finds that prompt a "hmm, really?" from us fact-focused journalists. This year's picks include a 1.45-million-year-old fossilized leg that may (or may not) show signs of cannibalism among hominids and a study positing that Earth's core has a secret inner chamber (Page 24).

Other achievements inspired delight without caveats, including the mathematical discovery of an "einstein tile" that creates an infinite pattern that never repeats (Page 32); the retrieval of RNA from an extinct creature for the first time (Page 32); and India's successful landing of the first spacecraft to alight near the lunar south pole (Page 35).

And though the pandemic is no longer headline news, the SARS-CoV-2 virus is still very much with us. Immunity gained through vaccines and infection has reduced the death toll from the ghastly levels seen in the pandemic's first three years. But the virus remains deadlier than the flu, with more than 1,000 people per week dying of COVID-19 this fall in the United States alone (Page 28).

The pandemic will remain a watershed event, both because of the carnage it wrought and because of the unprecedented scientific effort to create new vaccines and treatments to combat it. But other happenings that seem notable now will fade in time. Dig into the *Science News* archive online, and you'll find myriad examples of now-forgotten research that helped nudge a field along, as well as ideas that were just plain wrong, such as the 1940s recommendation that wallpaper be infused with DDT to kill pests (SN: 9/8/45, *p.* 147). A 1964 article reported uncritically on using nuclear bombs to dig a new Panama Canal (SN: 9/5/64, *p.* 149).

Science doesn't always get it right, but it does march on. Thank you for following that journey with us. — *Nancy Shute, Editor in Chief*

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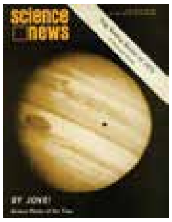
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Science News (ISSN 0036-8423) is published 22 times per year, bi-weekly except the first week only in May and October and the first and last weeks only in July by the Society for Science & the Public, 1719 N Street, NW, Washington, DC 20036.
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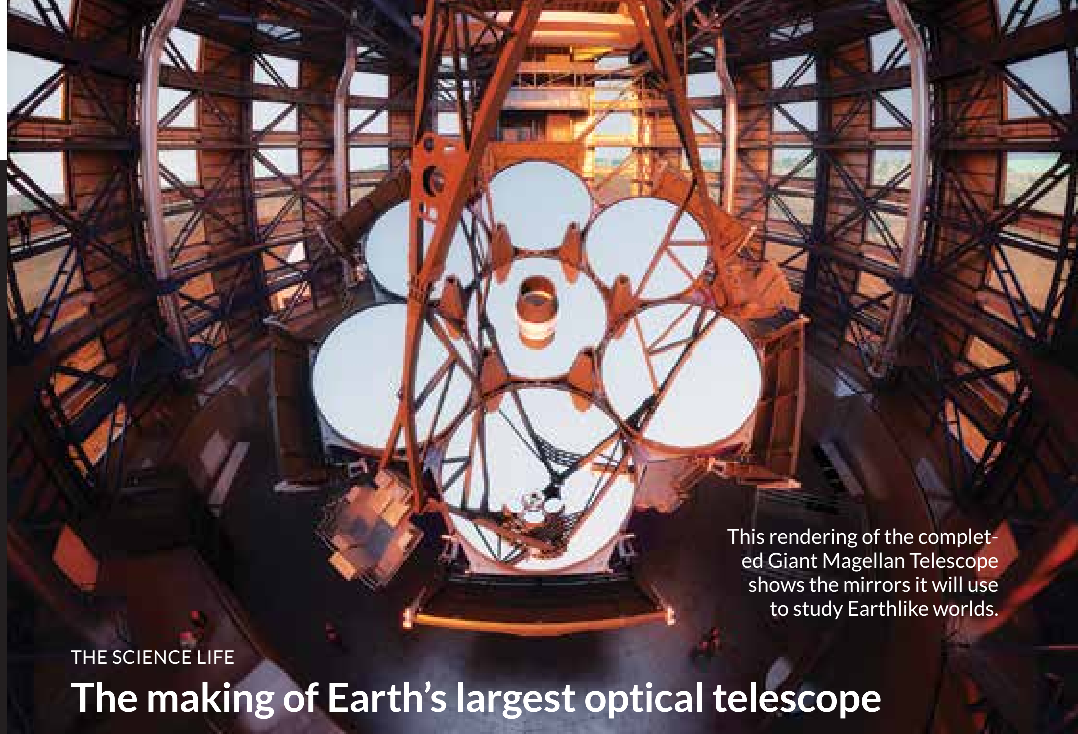
Excerpt from the December 22, 1973 issue of *Science News*

50 YEARS AGO

Flipper joins the navy

Porpoises, sea lions and even whales have been trained to retrieve dummy rockets and other objects from the bottom of the ocean.... The animals, guided by a homing device, would carry grappling hooks to submerged objects.... But whales became too expensive and kept running off to mate, so research now concentrates on smaller sea mammals such as porpoises.

UPDATE: Today, the U.S. Navy Marine Mammal Program, based in San Diego, trains bottlenosed dolphins and California sea lions to protect ships and harbors. Sea lions retrieve equipment from the ocean floor, dolphins locate underwater mines and both species detect unauthorized swimmers. Animals in the program have also helped researchers understand dolphin echolocation, assess the impacts of human-generated noise on wildlife and more. Current projects are testing whether it's possible to judge dolphins' health based on their whistles and whether a video game system can provide Navy sea lions with cognitive enrichment.



This rendering of the completed Giant Magellan Telescope shows the mirrors it will use to study Earthlike worlds.

THE SCIENCE LIFE

The making of Earth's largest optical telescope

Hot and dry air, perfused with a scent reminiscent of a hot hair straightener, stuffed a hangar-sized room beneath the football stadium at the University of Arizona in Tucson. The space, part of the Richard F. Caris Mirror Lab, was dominated by a gyrating, carousel-sized furnace, fire truck red and shaped like a flying saucer. The swirling cocoon of a colossal light collector.

"It's making 4.9 revolutions per minute," shouts Buell Januzzi, an astronomer at the university. On October 7, after about

TEASER

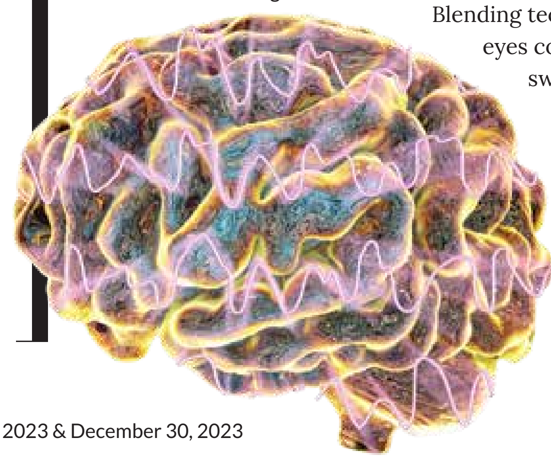
Knockout machine takes guesswork out of sedation

A new brain-monitoring device aims to be the Goldilocks of anesthesia delivery, dispensing drugs in just the right dose. Every 20 seconds, the machine adjusts how much propofol it doles out based on the electrical activity detected by implants in a patient's brain and a computer program that determines how the body is processing the drug.

In tests with two rhesus macaques, the device kept the monkeys conked out for 125 minutes, accurately shifting them between a lighter sedation and a deeper sleep, neuroscientist Emery Brown and colleagues reported October 31 in *PNAS Nexus*. The study is a step toward devising a system that will work for people.

Anesthesiologists often give more drug than necessary to ensure their patients remain unconscious during major medical procedures. Dose is based on body measurements like weight and age, but that calculation is not a perfect science. Blending technology with anesthesiologists' watchful eyes could take the guesswork out of hitting the sweet spot that keeps people in oblivion.

Adjusting anesthesia based on brain activity would help during long surgeries and could reduce patients' postsurgery delirium, says Brown, of MIT, Massachusetts General Hospital and Harvard Medical School. The next step is to make brain monitoring less invasive, substituting implantable electrodes for ones that attach to the scalp. — *Erin Garcia de Jesús*



Data on the brain's electrical activity (pink lines, illustrated) may improve how anesthesia is given.

FROM TOP: GIANT MAGELLAN TELESCOPE/GMTO CORPORATION; KATERYNA KON/SCIENCE PHOTO LIBRARY/GETTYIMAGES

a week of gradual warming, the temperature inside the rotating machine had finally peaked at 1165° Celsius.

In the heart of that inferno, roughly four semitruck loads of borosilicate glass had melted into a crystal clear fluid. If all goes to plan, the molten material will anneal to form an enormous mirror — one, if stood on its edge, as tall as a two-story house. The mirror is the last of seven needed to capture light for what will be Earth's most powerful optical instrument: the Giant Magellan Telescope.

Slated to start operating in the late 2020s, the telescope will repose on a mountaintop in Chile's Atacama Desert. There, within a 22-story enclosure, the seven primary mirrors, each 8.5 meters wide, will unite in a flowerlike formation, Januzzi explains. "We've got six petals, and one in the middle."

Together, the mirrors will function as a single unit, about as wide as an adult blue whale is long, that reflects light



Under a university football stadium in Tucson, a technician checks fired glass that will become a mirror in the Giant Magellan Telescope.

into the overlying secondary mirrors. This shiny expanse will provide the telescope with an image resolution at least four times that of today's most advanced space telescopes.

Unlike NASA's James Webb Space Telescope, best suited for measuring infrared light emitted by hot celestial bodies (see Page 42), the new telescope will capture optical and near-infrared light emitted by cooler, Earthlike worlds (SN: 4/22/23, *p.* 11). That's light that might carry signatures of alien life.

"It's going to give us the opportunity to find potentially habitable planets," says astrobiologist Antígona Segura of the National Autonomous University of Mexico in Mexico City.

It takes about a week for the furnace to heat and melt the glass, causing it to flow into a mold of hexagonal columns. After cooling and annealing for three months, the glass will resemble two pancakes sandwiching a honeycomb. The structure will be lightweight yet sturdy.

The mirror will then be polished over two years, yielding a surface so smooth that if it were expanded to the size of North America, the tallest imperfection would be half as tall as a golf tee. Finally, an ultrathin coat of aluminum will be applied to the clear surface. It's this last step that will enable the mirror to possibly capture glimpses of alien worlds, in wavelengths of light that our puny, human eyes can recognize. — *Nikk Ogasa*

SCIENCE STATS

Grassland fires threaten many homes

Forest fires can devastate vast swaths of land, but in the United States, another category of conflagrations poses a greater risk to homes.

Of the homes destroyed in wildfires across the contiguous United States from 1990 to 2020, 64 percent — nearly 11,000 — were razed by grassland and shrubland fires, researchers report in the Nov. 10 *Science*.

"We often think about forest fires because that's what we see on the news … they're dramatic, they're huge, they're intense," says ecologist Volker Radeloff of the University of Wisconsin-Madison. "But grassland and shrubland fires can also be quite destructive." For instance, the 2023 Lahaina fire on the Hawaiian island of Maui, fueled by invasive wild grasses, killed at least 98 people and destroyed some 2,200 buildings.

For the new study, Radeloff and colleagues analyzed three decades of data on wildfire occurrence, land use and housing to determine which vegetation types fed the most destructive fires and if homes had become more exposed to fires over time.

About 337,000 square kilometers of grasslands and shrublands burned from 1990 to 2020, compared with about 144,000 square kilometers of burned forest. Forest fires were twice as likely as grassland fires to burn down buildings they encountered, but because grassland and shrubland fires burned a much greater area, they destroyed more homes overall.



The Marshall fire burned through grasses near Boulder, Colo., in 2021, destroying over 1,000 homes and killing two people. Blazes in U.S. grasslands and shrublands are destroying more homes than forest fires.

The data also revealed that more U.S. homes may now exist in areas vulnerable to wildfires. As of 2010, roughly 148,000 houses stand in areas where wildfires have burned before — that's more than twice as many as in 1990. About half of the additional homes were built on land that had already burned before 1990, the team found, while the rest were already standing when a blaze burned through.

Radeloff hopes more people will consider their wildfire risk and take steps to prepare, be that planning evacuation routes or fireproofing their homes (SN: 5/9/20 & 5/23/20, *p.* 28). Evading wildfire danger, it seems, takes more than getting out of the woods. — *Nikk Ogasa*

FROM TOP: DAMIEN JEMISON, GIANT MAGELLAN TELESCOPE/GMTO CORPORATION; MILEHIGHTRAVELER/GETTYIMAGES

News

ANIMALS

Wild bonobos socialize like humans do

The finding may help shed light on the evolution of cooperation



Unrelated bonobos in different social groups, including this adult female and adolescent male in Congo, cooperate without immediate payoff.

M. SURBECK/KOKOLOPORI BONOBO RESEARCH PROJECT

BY JAKE BUEHLER

Humans regularly cooperate and share resources with unrelated humans in different social groups without any immediate, reciprocated benefits. The phenomenon has been considered unique to our species. But some bonobos appear to share the social trait, a study finds.

This type of cooperation is thought to underpin human civilization. So bonobos' ability to cooperate with unrelated groups when there's no immediate payoff may provide some insight into the evolutionary conditions that led to humankind's large-scale societies, researchers report in the Nov. 17 *Science*.

Both chimpanzees (*Pan troglodytes*) and bonobos (*P. paniscus*) live in social groups with individuals that may not be very closely related. But compared with territorial and aggressive chimpanzees, bonobos have a more easygoing, tolerant attitude toward other groups. Bonobos occasionally groom and share food with unrelated individuals from other social groups and have even been known to adopt outsiders' young (SN: 4/10/21, *p.* 12). But the extent of this cooperative behavior has been unclear.

So behavioral ecologists Liran Samuni of the German Primate Center in Göttingen and Martin Surbeck of Harvard University studied two bonobo groups in Congo's Kokolopori Bonobo Reserve. Over two years, the researchers recorded which bonobos exchanged grooming services and shared food, and when. They also recorded instances of conflict, such as when the apes formed alliances with members of the other group to attack a third individual.

The two groups interacted with each other nearly 100 times, sharing 20 percent of the study period in each other's company. Meetings between the groups lasted anywhere from an hour to multiple weeks, which allowed long-term bonds to develop.

Of more than 3,700 grooming interactions, 10 percent were between bonobos of different social groups. Six percent of all food shares were across groups. And of all partnerships formed to attack a third individual, 15 percent were between bonobos of different groups.

The cooperation wasn't "a one-off kind of thing," Samuni says. Individuals that tended to engage in cooperative behavior within their group were more likely to interact with bonobos in the other group that had the same tendency. And it doesn't appear to be solely motivated by immediate reciprocation. For instance, just 14 percent of bonobos that shared food across groups had the deed reciprocated.

The findings build on observations of similar behavior in captive bonobos, hinting that this type of cooperation is intrinsic to the species. Many animals will cooperate with relatives, perhaps because it indirectly encourages the proliferation of one's own genes. When helping nonrelatives, the benefit is even more indirect, so this form of cooperation may not evolve as readily.

For instance, vampire bats, bonobos and humans are among the few animal species known to share food among unrelated individuals, Samuni says. Chimps do it too, but only within the same social group. In human evolution, such sharing "is considered one of those behaviors that supported our societies," Samuni says.

Our own species's behavior makes the new result particularly interesting, says comparative cognitive psychologist Shinya Yamamoto of Kyoto University in Japan. "Humans sometimes compete or fight with neighboring groups, but other times we cooperate even with outgroup members," Yamamoto says. Among our primate relatives, there are plenty of examples of aggression and competitiveness. But the evolutionary origins of humankind's cooperative side remain unclear.

Humans are equally genetically related to chimpanzees and bonobos, and the findings don't tell us whether early human ancestors were more like hostile chimps or relaxed bonobos. But the research could shed light on "what shifts the needle from one to the other," Surbeck says.

Cooperation between groups may not be as heavily influenced by cultural factors and social norms, which have been considered necessary for cooperation in humans, Samuni says. In bonobos, the system is quite simple and emerging "in a way that is quite similar [to humans]," she says.

Other bonobo groups have differing rates of intergroup interaction, Yamamoto says, so studying more of the apes might reveal something akin to social norms. ■



PHYSICS

Light alone may help evaporation along

If real, the effect could be occurring naturally all over the world

New research suggests light could be breaking bonds between water molecules in sea-foam, soil and other places where water mingles with air.

TINA TERRAS & MICHAEL WALTER/MOMENT/GETTY IMAGES

BY EMILY CONOVER

Green light means "go." That might apply to evaporating water molecules too.

Visible light, especially that of a greenish hue, might spur water to evaporate, scientists report in the Nov. 7 *Proceedings of the National Academy of Sciences*. In lab tests, water evaporating under visible light showed a higher evaporation rate than possible based on heat alone, MIT mechanical engineer Gang Chen and colleagues say.

Coupled with other observations, they say, the finding suggests that when light shines on water, individual particles of light, or photons, can sever the bonds between water molecules, releasing clusters of molecules into the air.

"This is super exciting stuff," says Yuki Nagata, a chemist at the Max Planck Institute for Polymer Research in Mainz, Germany, who was not part of the research. He notes that the hypothesis needs additional checking. "We are not 100 percent sure this is really the mechanism," he says. But if it is, it's "totally new."

Typically, heat is what gets evaporation going, causing water molecules in the liquid to jostle more vigorously. That extra energy can break some of the bonds between molecules in the liquid, allowing molecules to escape as water vapor. Based on how much heat goes in, scientists can calculate the amount of evaporation expected. Visible light can help water evaporate due to the heat it imparts. But until now, it wasn't thought to directly break the bonds between water molecules.

In the new study, Chen and colleagues shined light on water contained in porous hydrogels, materials that greedily sop up water. The proposed effect occurs where air meets water, and the hydrogels used in the study contain innumerable crannies where the two mingle, allowing water to be cleaved off and escape. In some cases, the evaporation rate was more than double the expectation based on heat. What's more, the evaporation rate varied with the wavelength of the light. Green light produced the highest evaporation rate.

That wavelength dependence is convincing support for the researchers' hypothesis, says thermodynamicist Janet A.W. Elliott of the University of Alberta in Edmonton, Canada. "If you just shine [visible] light on something, how do you know if it's the light or the heat from the light that's doing your job? But if it's wavelength dependent … that's evidence that the light part of it matters." Additionally, the excess evaporation didn't occur when a heater was used instead of light, she says.

When heat drives evaporation, molecules typically escape one at a time. But measurements of the temperature of the vapor above the hydrogel suggest that when light is driving the evaporation, water molecules escape in clusters. Then the clusters themselves evaporate, breaking into individual water molecules, cooling the vapor in the process.

In general, the vapor temperature was higher closer to the hydrogel, just as steam is hottest directly above a boiling pot. But in a pocket of vapor from about eight to 14 millimeters above the surface, the temperature didn't vary with height. That, the team says, is evidence of a region where the air is saturated with individual water molecules, and where clusters continually evaporate and recondense.

"It's pretty convincing that, in this particular experimental setup, you can see clumps of molecules coming off and then those clumps evaporate," Elliott says.

But, she says, there are "still lots of questions to be answered." For example, the researchers don't explain in detail how the photons could break the bonds or why it works best with green light.

Chen admits that the theoretical explanation involves some hand-waving. Still, he hopes that this effect could be put to use for practical purposes, such as more efficient ways of making freshwater from salt water (SN: 8/20/16, p. 22).

The effect might be widespread in nature, Chen says, in water within porous materials like soil or plants, or in foams on the surface of the ocean. "We have a feeling this is really happening daily, widely, and that's why we're very excited" about the finding. ■

NEUROSCIENCE

Brain data hint at teens' mental health

MRI scans find a link between neural connections and resilience

BY LAURA SANDERS

WASHINGTON — Brain scans could be used to predict how teenagers' mental health will fare during a stressful time, an analysis that spans the COVID-19 pandemic suggests.

The neural details revealed by these brain scans, presented November 13 in a news briefing at the annual meeting of the Society for Neuroscience, may help explain why some people succumb to stress while others are more resilient.

For a lot of research, "the study happens, and you report on the results, and that's about it," says Margot Wagner, a bioengineer at the University of California, San Diego who was not involved in the new work. But this research followed hundreds of U.S. teenagers over time, a study design that raises the possibility that "you can intervene and help way sooner than otherwise," Wagner says.

> "Without the pandemic, we would not have been able to understand the impact of a long-lasting adverse event."
>
> CATERINA STAMOULIS

The pandemic was particularly tough for many teenagers, as isolation, worry and upheaval of daily routines affected them in ways that scientists are just now starting to see. A record number of young people are struggling with depression and anxiety, part of a mental health crisis that some scientists are calling "the second pandemic" (SN: 7/1/23, *p.* 18).

While many teenagers struggled during the pandemic, others did OK. Computational neuroscientist Caterina Stamoulis of Harvard Medical School and Boston Children's Hospital investigated why responses differed using data collected as part of the Adolescent Brain Cognitive Development, or ABCD, study. That larger study — involving scientists at 21 research sites across the United States — aims to figure out how teenagers' brains develop.

"This is the first time in history we're looking at thousands of participants and getting these measures over time," Wagner says. "It's truly remarkable."

The ABCD study, which began in 2015, was well under way when COVID-19 hit, so researchers possessed brain scans from before the pandemic. "Without the pandemic, we would not have been able to understand the impact of a long-lasting adverse event" that deeply affected all of the participants' lives, changing their interactions with their family and friends, Stamoulis says.

At the outset of the project, functional MRI brain scans measured blood flow — a proxy for brain cell activity — in more than 1,400 teenagers, a subset of the nearly 12,000 adolescents enrolled in the ABCD study. The fMRI images recorded how certain regions of the brain behave in tandem with each other, a clue that those regions work together in what neuroscientists call a brain circuit.

"Neuroimaging data is particularly useful for developing predictive models of future outcomes, including resilience to stress, depression and many other things," says Vince Calhoun, a neuroscientist and engineer at Georgia Tech who was not involved in the study.

In May 2020, as the world felt the effects of the pandemic, researchers started surveying the teenagers in the study about how they were holding up. These surveys, sent every few months, measured aspects of mental health, stress and sadness, among other things.

Teenagers who had weaker neural connections between certain parts of the brain before the pandemic fared worse than teenagers with stronger neural connections, the team found. These brain regions included the prefrontal cortex, a brain area important for attention and planning that is still developing during adolescence, and the amygdala, a structure on each side of the brain that's involved in emotions. Weaker brain connections were associated with kids having more sadness and stress during the pandemic.



Teenagers who had weaker connections between certain parts of the brain before the COVID-19 pandemic were more prone to sadness and stress during the pandemic than teens who had stronger connections, a study finds.

JO MCRYAN/DIGITALVISION/GETTY IMAGES

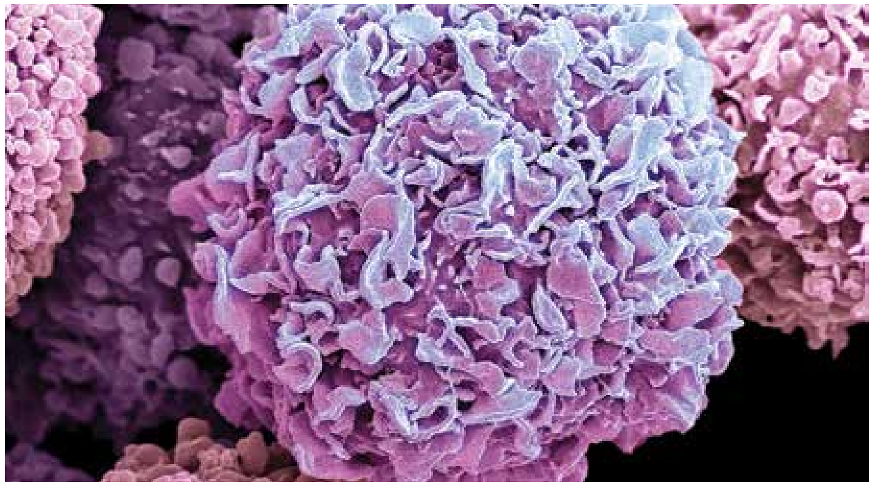
But there's another way to look at the results, Stamoulis says. "Stronger and more resilient brain networks predicted better mental health, lower stress and lower sadness."

Stamoulis and colleagues plan to study these brain circuits as time goes on. As brains develop, they respond to experiences and environments. If those are positive, she says, they can be "protective factors for the brain and how its circuits evolve and become wired." ■

HEALTH & MEDICINE

A gene may blunt a breast cancer drug

The variant impairs tamoxifen's ability to tackle tumor cells



The breast cancer drug tamoxifen leverages a protein in the body to keep cancer cells (purple in this false-color scanning electron micrograph) from growing. About a fifth of Africans on average may have a version of the protein that might make tamoxifen less effective.

STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY/GETTY IMAGES

BY SAIMA S. IQBAL

WASHINGTON — A genetic variant commonly found in some Africans may stymie the effects of a widely used breast cancer drug.

The variant instructs cells to make a sluggish version of the enzyme known to activate tamoxifen. People who inherit two copies of the variant have only a fifth as much active drug in their bloodstreams as people who don't have that variant, researchers reported November 2 at the American Society of Human Genetics annual meeting. As a result, many of these patients may receive a dose of tamoxifen that's insufficient to treat their cancer.

The gene that codes for the crucial enzyme is called *CYP2D6*, and it differs dramatically among people. On average, a fifth of Africans carry at least one copy of the variant that the team studied. Across the continent, however, that figure ranges from a slim 5 percent to over 34 percent.

Preemptive genetic screening that identifies patients with the variant would probably cost too much for local clinics and hospitals, says molecular geneticist Comfort Kanji of the African Institute of Biomedical Science and Technology in Harare, Zimbabwe. But his team's findings could inspire clinical trials that test larger starting doses of tamoxifen in heavily affected groups, Kanji says.

Kanji and colleagues collected daily blood samples from 42 Zimbabweans taking tamoxifen. Some of the participants had one copy of the variant, while others had two. A third group had a different version of the gene with no known effect on the enzyme. The differences in how the patients metabolized the medication emerged right away and remained for the duration of the 3-week-long experiment.

Additionally, simulations suggested that doubling the prescribed amount of the drug for participants with two copies of the variant would bring levels of active drug in the blood back to normal — and with few short-term consequences.

The study provides powerful results despite a small sample size, says David Twesigomwe, a pharmacogeneticist at the Sydney Brenner Institute for Molecular Bioscience in Johannesburg. And it offers a clear-cut case for metabolic screening. Comprehensive genetic testing remains out of reach for many Africans, but simpler, narrower tests could potentially lay the foundation for clinicians to incorporate screening more widely in treatment, Twesigomwe says.

Nearly 200,000 people in sub-Saharan Africa receive diagnoses of breast cancer each year. Roughly 40 percent survive for longer than five years past their diagnosis, unlike 86 percent in the United States. The main reason is that many patients in Africa struggle to access or afford screenings and treatment, and as a result, show up at clinics with late-stage cancers. This new finding is unlikely to turn those cases around, but it could help make timely care more effective, Kanji says.

40 percent
The five-year survival rate for people with breast cancer in sub-Saharan Africa

86 percent
The five-year survival rate for people with breast cancer in the United States

Worldwide, about 30 percent of patients with estrogen receptor–positive breast cancer — the most common type — show little improvement on tamoxifen. Among African women, the proportion is about 50 to 60 percent, Kanji says. The prevalence of the studied gene variant, or others with a similar effect, could offer a partial explanation.

A separate study would be required to see if the findings extend to African Americans, Kanji and Twesigomwe both say. In the United States, Black women are 40 percent more likely to die of breast cancer — with about 28 deaths per 100,000 for Black women compared with 20 per 100,000 for white women — despite a similar rate of diagnosis.

Experts caution that the reasons why are multifaceted, including biological, sociological and historical. The role that a variant of *CYP2D6* plays may constitute a sliver of a sliver.

The enzyme that the gene generates metabolizes more than just tamoxifen. It's responsible for breaking down many other drugs, including opioids, beta-blockers and a common class of antidepressant drugs called selective serotonin reuptake inhibitors. That means that people with different variants of the gene may respond better or worse to those medications too. ■

ANIMALS

Mouse embryos OK after space travel

Harsh conditions may not immediately threaten reproduction

BY SAIMA S. IQBAL

Mouse embryos can make it to an early stage of development in space.

In 2021, a few hundred frozen two-celled mouse embryos thawed and grew over four days on the International Space Station. Of the several dozen embryos that made it back to Earth alive, nearly a quarter formed healthy clusters of cells known as blastocysts.

The finding suggests that the radiation and weightlessness of space might not completely hinder mammalian reproduction, researchers report in the Nov. 17 *iScience*.

The study isolates only one part of the complicated process of reproduction. But the result provides a starting point for biologists, says Christiane Hahn, a space biologist at the European Space Agency's Human Spaceflight and Robotic Exploration Program in Noordwijk, Netherlands, who wasn't involved in the research.

Mouse embryos are the first mammalian embryos that researchers have grown in space, an important step in understanding how space affects human reproduction. Other experiments have involved fish, amphibians and birds.

Previous research has suggested that the conditions in space might be harmful to the early stages of reproduction in mice. When in space, the animals have been too stressed to mate, and their eggs can accumulate mutations due to radiation, studies have shown. Freeze-dried mouse sperm, however, can remain viable after several years on the International Space Station (*SN: 7/3/21 & 7/17/21, p. 16*).

To overcome the challenges, biologist Teruhiko Wakayama and colleagues fertilized mouse eggs, froze the embryos at the two-celled stage and sent them to the space station in a specially made device. After the experiment ended, embryos were returned to Earth. Out of 360 embryos, 72 survived. And 17 of the survivors had developed into normal blastocysts — their cells had become precursors of fetal or placental tissue. A blastocyst typically forms a few days after fertilization and implants in the uterus, developing into the placenta and fetus.

Future alterations to the procedure might increase the success rate, says Wakayama, of the University of Yamanashi in Kofu, Japan. The absence of perfectly sterile conditions in the space experiment probably exacerbated cell death, he says.

Blastocysts can't survive for long outside of the uterus, so the experiment was designed to last only a few days. To find out how the cells would fare as development unfolds, the team wants to impregnate female mice with viable embryos from space experiments.

The scientists are especially interested in examining how microgravity may impact the positioning of different types of cells in a blastocyst. Precursor fetal cells typically sink to the bottom of the cluster and are encased by precursor placental cells. If the fetal cells split in two, then they'd have lower survival rates. If they split further, then the blastocyst would probably be unviable. In the new study, three-quarters of the precursor cells appeared to settle in the right spot. Fully understanding microgravity's effect on the cells will take more work. ■



S. WAKAYAMA *ET AL*/*ISCIENCE* 2023

Mouse embryos cultured on the International Space Station formed blastocysts (some shown). The work is a step in understanding how space may affect human reproduction.

ANIMALS

Mapping crabs' evolutionary odyssey

The crustaceans departed the sea not once, but several times



Crabs, such as this ghost crab on Namibia's coast, persist everywhere from deep-sea hydrothermal vents to steamy mountainside jungles.

JAMI TARRIS/GETTY IMAGES

BY AMANDA HEIDT

Most groups of terrestrial plants and animals left the ocean a single time in their evolutionary history to live ashore. But crabs have seemingly scuttled out of the sea more than a dozen times, new research suggests, with at least two groups later reverting back to a marine lifestyle.

The research, published November 6 in *Systematic Biology*, not only sheds light on the evolutionary history of the infraorder Brachyura, which includes about 7,600 species of "true crabs," but it also provides the most comprehensive evolutionary tree yet created for the group. And the findings offer clues about how other arthropods may have evolved a terrestrial lifestyle, the researchers say.

Unlike for well-studied animals such as birds and mammals, scientists have lacked a unified crab tree of life, says Kristin Hultgren, an invertebrate zoologist at Seattle University. "While the authors have developed a useful framework for understanding the complexity of transitioning to terrestrial life, one of the most important contributions is the extensive, well-dated evolutionary tree."

Crabs are an extremely diverse group and have colonized nearly every type of habitat on Earth. It's been a challenge to study when crabs first shifted from one habitat to another during evolution, because, like some other invertebrates, crabs don't have the extensive fossil trail that early vertebrates do, says evolutionary biologist Joanna Wolfe of Harvard University.

Past research has also often treated marine, freshwater and land crabs as discrete subgroups, when they are more like a continuum, Wolfe says. "They're not distinct and actually have a lot in common, and looking at them together helps trace their evolution."

Wolfe and colleagues collected genetic data from 333 species of true crabs. These crustaceans are evolutionarily distinct from, although closely related to, another group of crustaceans that independently evolved crablike bodies and are often erroneously referred to as crabs, including hermit and king crabs.

The team then combined that genetic data with data from dozens of fossils to generate a crab evolutionary tree, layering on details about each species's life history and adaptations for living on land to reconstruct a possible timeline of when crabs colonized drier ground.

True crabs diverged from other crustacean lineages roughly 230 million years ago during the Triassic Period, the team found. Millions of years later, brachyurans diversified widely during a period previously dubbed the "Cretaceous Crab Revolution."

The study also showed that during their evolution, crabs appear to have adapted to a more terrestrial lifestyle as many as 17 times—either by shifting from the ocean to the intertidal zone or similarly salty habitats like mangroves, or by colonizing freshwater estuaries and rivers en route to land. In at least two cases, crabs reverted to a marine lifestyle long after they'd left.

The amount of times that crabs independently left the ocean is "astonishing," says Katie Davis, an evolutionary paleobiologist at the University of York in England who was not involved in the research. "And it's really fantastic that molecular biology, fossils and modern numerical techniques can be combined to provide insight into previously unanswerable questions."

What's more, the findings hint at what other early arthropods that ventured onto the land may have been like, Wolfe says. Previous studies have shown that crustaceans and insects share a common, if unknown, aquatic ancestor. By looking at types of crabs that successfully left the ocean, it's possible to guess at what adaptations early insects might have needed to do the same. Modern crabs living out of the water today, for example, excel at keeping themselves from drying out and have limited their dependence on water for reproduction.

"If you're going to be the first protoinsect to come out of the ocean…you're probably going to need those kinds of adaptations," Wolfe says. ■

ANIMALS

Hummingbirds show off a flight trick

Cameras record the birds flying sideways through narrow gaps

BY ERIN GARCIA DE JESÚS

Hummingbirds are natural acrobats, twisting their wings in ways that let them fly backward and upside down, unlike any other bird. Now, high-speed video shows how, using aerial gymnastics, the birds can slip through gaps narrower than their wingspan.

Anna's hummingbirds (*Calypte anna*) fly sideways to make it through holes too small for their stiff, outstretched wings, scientists report November 9 in the *Journal of Experimental Biology*. The birds flutter their wings at a fraction of the full range of motion, keeping them from hitting the hole's sides while preserving the backward flying ability. After navigating the obstacles a few times, hummingbirds flatten their wings against the body and shoot like a bullet through the holes.



Hummingbirds' wings don't easily bend, making it difficult for birds like this male Anna's hummingbird to fly through gaps smaller than their wingspan.

"This is a new insight into the amazing capacity of hummingbirds," says Bret Tobalske, a biomechanist at the University of Montana in Missoula who was not involved in the study. Most birds just pull their wings close to the body to fly through dense vegetation. Sideways flight highlights how unique these hummingbirds are, Tobalske says.

Biologist Marc Badger and colleagues trained four wild Anna's hummingbirds to fly between two feeders, then introduced barriers monitored by high-speed cameras. Each barrier had holes ranging from 6 to 12 centimeters across, equivalent to about half or a full hummingbird wingspan.

The sideways maneuver shocked study coauthor Robert Dudley, a physiologist at the University of California, Berkeley. "To slow it up and then go sideways and not drop in altitude was a novel behavior."

Perhaps hummingbirds fly sideways to navigate obstacles that might hide predators, says Badger, who did the work while at UC Berkeley. Once the birds know it's safe, they use the ballistic technique to avoid breaking feathers, he suggests. ■

ANIMALS

Darwin wasps get a boost in Brazil

A cache of species hints the wasps are diverse in the tropics

BY DARREN INCORVAIA

Teeming with life, the tropics tend to hold far more species than milder environments closer to the poles. One family of insects known as the Darwin wasps were thought to buck that trend.

But sifting through insects taken from a mountain in the Brazilian Atlantic rainforest revealed 98 species of Darwin wasp, three-fourths of which are new to science, researchers report in the November *Insects*. The finding suggests the tropics are home to far more types of the wasp than was previously recognized.

Scientists had thought that this vast group was most diverse at midlatitudes based on a comparison of wasp diversity in temperate areas in the United Kingdom and United States with tropical regions elsewhere in the world. But it's easier to look for wasps in a British garden than it is to do long-term work in a tropical rainforest, says biologist Peter Mayhew of the University of York in England. Still, he was up for the challenge.

To understand where Darwin wasps might live in the tropics, Mayhew and colleagues placed jars of alcohol at 15 sites on a mountain in Brazil's Serra dos Órgãos National Park. The alcohol in each trap became "insect soup," Mayhew says. So the team focused on a subfamily called pimplines. Mayhew plans to search for other types of Darwin wasps in the soup, he says.

The finding confirms that the wasps have "this amazing unexplored diversity in the tropics," says conservation biologist Laura Timms of the environmental organization Credit Valley Conservation in Mississauga, Canada. For comparison, the British Isles have 109 known pimpline species, and wasp diversity there has been sampled much more than in Brazil.



This brilliant blue *Pimpla caerulea* is among the Darwin wasps that scientists found living on a mountainside in Brazil.

Darwin wasps lay eggs on or inside other insects so that their larvae have a ready-made meal upon hatching. In this way, the wasps play a vital ecological role: population control. "We need more people working on them," Timms says. ■

FROM TOP: NICHOLAS CHESARINO; KARI KAUNISTO/BIODIVERSITY UNIT/UNIV. OF TURKU







2023
YEAR IN REVIEW

In recent years, human-caused climate change has repeatedly had a prominent spot in our annual look back at the year in science. These stories fall into one of two categories: They are about record-breaking heat waves, wildfires, tropical storms and other deadly natural disasters, or they offer glimmers of hope for turning things around. This year, it was hard to find good news amid the oppressive heat that roasted many parts of the world and briefly turned parts of the Atlantic Ocean into a hot tub. Yet there's plenty of hope to be found elsewhere. Other highlights of 2023 demonstrate what astounding feats science can accomplish, from editing human genes in order to fix genetic diseases to designing a robot that can fly to an asteroid and return with a bounty of space rocks. Those feats suggest, if given the chance, human ingenuity could yet overcome climate change.





A year of extreme, unrelenting heat

This year didn't just shatter climate records. It changed the scales.

Graph after graph tracking this year's soaring global temperatures reveal that not only were the numbers higher than ever recorded in many places around the world, but the deviation from the norm was also astonishingly large.

"The margins by which records are being broken this year have surprised not just me but [other climate scientists] that I trust," says climate scientist Doug McNeall of the U.K. Met Office Hadley Centre in Exeter, England.

As of late November, months of sweltering global temperatures put 2023 on track to be Earth's hottest year since record-keeping began about 150 years ago. The 12-month period from November 2022 through October 2023 is officially the hottest such period on record — a record that's likely to be broken in 2024, according to the nonprofit group Climate Central (*SN: 12/2/23, p. 6*).

Extreme heat waves baked many regions, which in turn fueled catastrophic wildfires. Ocean heat was off the charts, with global average sea surface temperatures sustaining record highs for most of the year. And in the water surrounding Antarctica, sea ice reached new lows.

These records had the fingerprints of human-caused climate change all over them, according to the international scientific consortium World Weather Attribution. Climate change made July's extreme heat waves in North America, Southern Europe and North Africa hundreds of times as likely, and another in China about 50 times as likely (*SN Online: 7/25/23*). Climate change was also the primary cause behind a brutal winter and early spring heat wave in South America, making that event at least 100 times as likely.

On social media, many climate scientists who posted screenshots of 2023's temperature anomalies struggled to find words to explain them. "Surprising. Astounding. Staggering. Unnerving. Bewildering. Flabbergasting. Disquieting. Gobsmacking. Shocking. Mind boggling," Ed Hawkins, a climate scientist at the National Centre for Atmospheric Science at the University of Reading in England, wrote on X, formerly Twitter, about September's temperatures.

Record-breaking heat

From January through September, Earth's average global surface air temperature was about 1.1 degrees Celsius (about 2 degrees Fahrenheit) higher than the 20th century average of 14.1° C (57.5° F).

From June through October, each month was the hottest of its kind ever recorded. September was hotter than an average July from 2001 to 2010. The year isn't out yet, but temperatures so far suggest 2023 has a greater than 99 percent chance of being the hottest year on record, according to the U.S. National Centers for Environmental Information.

The Southern Hemisphere had a particularly sweltering winter and early spring, with temperatures in August and September soaring above 40° C (104° F) across parts of Brazil, Paraguay, Bolivia and Argentina. In some areas, daytime temperatures were about 20 degrees C (36 degrees F) above normal. Madagascar had its warmest October on record, with some spots 2.5 degrees C (4.5 degrees F) above average.

> "The margins by which records are being broken have surprised not just me, but [other climate scientists] that I trust."
> **DOUG MCNEALL**

The second half of 2023 saw the onset of an El Niño climate pattern, which generally means higher global temperatures, says John Kennedy, a climate scientist with the U.N. World Meteorological Organization. But most El Niño–related warming generally comes the year *after* an El Niño event, he says, as the heat that's been accumulating in the eastern equatorial Pacific Ocean gets transported elsewhere. That's what happened in 2016, previously the hottest year on record (*SN Online: 7/13/23*).

Ocean temperatures began reaching new highs long before El Niño kicked in. From late March through October, the world's average sea surface temperature consistently broke daily records. By July, these temperatures were nearly 1 degree C (about 1.8 degrees F) above average, as marine heat waves racked nearly half of the global ocean, compared with a more typical 10 percent.

Such warm waters are unprecedented in the modern record — and possibly in the last 125,000 years, researchers note (*SN Online: 8/9/23*). Ocean life suffered as the relentless accumulation of all that heat took its toll. Coral reefs, for instance, suffered widespread bleaching across the Gulf of Mexico, the northern Atlantic Ocean, the Caribbean Sea and the eastern Pacific Ocean.

Heat harms health

Most of the unprecedented temperatures to hit the news were daytime maximums, but the record-breaking heat continued into the night, endangering human health.

On July 6, the city of Adrar, Algeria, faced the hottest night ever recorded in Africa: Nighttime temperatures never dipped below 39.6° C (103.3° F). And just after midnight on July 17, a weather station in Death Valley, Calif., recorded a temperature of 48.9° C (about 120° F). If confirmed, that is the highest temperature ever recorded anywhere for that dark hour.

In most parts of the world, nights have been warming faster than days for decades. That's a concern because when nights are hot, the body loses a chance to recover from the heat of the day (*SN Online: 8/6/23*).

Balmier bedtime temperatures also diminish the quantity and quality of sleep. Last year, data scientist Kelton Minor of Columbia University and colleagues published an analysis of billions of sleep-duration measurements

OPPOSITE PAGE, CLOCKWISE FROM TOP LEFT: DAVID MCNEW/GETTY IMAGES NEWS; SPENCER PLATT/GETTY IMAGES NEWS; BRANDON BELL/GETTY IMAGES NEWS (LAST TWO)

from nearly 70 countries. The team estimated that, as of 2017, warmer nights around the world contributed to eroding an average of 44 hours of sleep from each person every year.

Extrapolating to this year's extreme heat, Minor says, "you would expect that this summer, on a global scale, would have eroded probably the most [sleep] in the observational record."

Extreme heat can also lead to heat stroke, cardiovascular and respiratory diseases, and death. And heat-related deaths have been on the rise for years.

In many parts of the world—such as Africa, where a prolonged spring heat wave in Madagascar would have been virtually impossible without climate change, according to World Weather Attribution—the number of lives lost to extreme heat is unknown. But an analysis of Eurostat data estimated that in Europe last year there were more than 60,000 heat-related deaths, up from around 40,000 in 2018. Provisional data from the U.S. Centers for Disease Control and Prevention indicate that over 1,700 people in the United States died from heat in 2022. That's more than four times as many U.S. lives lost to heat just eight years earlier.

It appears 2023 may have continued the trend. By October, hundreds of heat-related deaths had been reported from many counties in the American Southwest, where people sweltered through some of the summer's highest temperatures. A record-breaking 579 such deaths have so far been reported out of Arizona's Maricopa County—the fourth most populous county in the United States—up from 386 confirmed fatalities in 2022. Neighboring Pima County reported 175 heat-related deaths this year, up from 58 the previous year.

One problem is the danger of heat is often underestimated, says Kristie Ebi, a climate and health researcher at the University of Washington in Seattle.

Moving forward, it will be crucial to spread greater awareness about the dangers and to invest in more interventions like cooling centers and urban green spaces. "Nobody needs to die, and this is not like somebody being caught in a flash flood," Ebi says. "There is enough known that it's possible to protect people."

Wildfires burn away

Hotter nights may have also exacerbated wildfires. "In the past, you would get a drop in temperatures overnight, and that would help abate the wildfire spread," says climate and atmospheric scientist Danielle Touma of the University of Texas Institute for Geophysics in Austin. "But more recently, especially during a heat wave, these temperatures have not been dropping as much as they used to," she says. "That means that the fire continues to spread overnight."

This year, heat contributed to an especially bad fire season in the Boreal region, a colossal area that wraps around the Earth just south of the Arctic Circle and contains close to one-third of the world's forests. The largest intact stretch of this forest lies in Canada, which had its worst fire year on record. Hundreds of megafires burned across the country, and some 200,000 people were forced to evacuate. Blazes in Quebec billowed smoke that engulfed the U.S. East Coast and Midwest, turning the skies orange and subjecting millions to hazardous air quality (*SN Online*: 6/9/23). As of October, the area burned in Canada surpassed 180,000 square kilometers, an area larger than Greece, more than doubling the previous national record from 1995.

Wildfires contribute to carbon emissions, which intensify global warming. The estimated carbon emissions from the Canadian fires amounted to nearly 410 million metric tons, shattering another record for the country. That's more than a quarter of the world's wildfire emissions this year.

As a whole, though, 2023's wildfire emissions didn't break global records. In fact, emissions have been decreasing for decades, largely because humans have cleared away many forested areas for agriculture, decreasing the area where wildfires could burn (*SN*: 6/17/23, *p*. 18).

Nonetheless, terrifying wildfires scorched many parts of the world.

In the Northern Hemisphere, summer heat contributed to a wildfire in Greece that became the largest ever recorded in the European Union. In Hawaii, a wildfire fueled in part by drought destroyed much of the town of Lahaina and left at least 99 dead, making it the deadliest U.S. wildfire since 1918. Meanwhile, the Southern Hemisphere's warm winter helped fires spread in many regions, including

In July, the world's hottest month on record, heat contributed to the spread of hundreds of wildfires in the Canadian provinces of British Columbia and Alberta, which billowed huge plumes of smoke that are visible in this satellite image.



LAUREN DAUPHIN, MODIS/LANCE/EOSDIS/NASA, WORLDVIEW/GIBS/NASA

Argentina and the Amazon rainforest.

In Australia, a spring heat wave helped the fire season kick off early; by August, around 70 blazes had already been reported out of New South Wales, the country's most populous state, two months before the official start of the bushfire season in that state.

New lows for Antarctic sea ice

Dwindling sea ice in the Arctic has become a familiar story in recent decades, while the southernmost continent's sea ice has waxed and waned more erratically.

But in the last few years, satellite data have shown an uptick in the rate of sea ice loss in Antarctica, says climate scientist Mark Serreze, director of the U.S. National Snow and Ice Data Center in Boulder, Colo.

Then came 2023. Antarctica's sea ice "just plummeted," Serreze says.

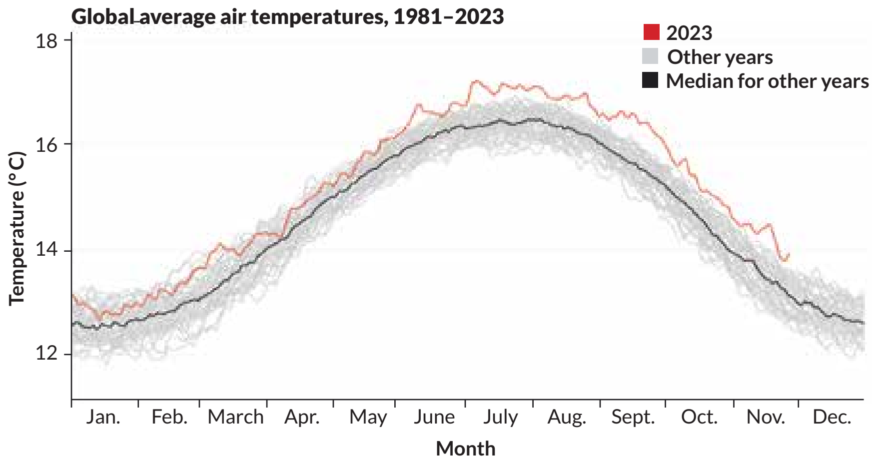
The sea ice expanse was at record-low levels for much of the year (SN *Online*: 7/5/23). February, the peak of summer, saw a record low minimum extent. By late July, the height of winter, the sea ice was more than 2.6 million square kilometers below the 1981–2010 average. On September 10, the ice hit its annual maximum at about 17 million square kilometers. That's roughly 1 million square kilometers smaller than the previous lowest maximum in 1986.

These numbers were "far outside anything observed in the 45-year modern satellite record," Serreze says.

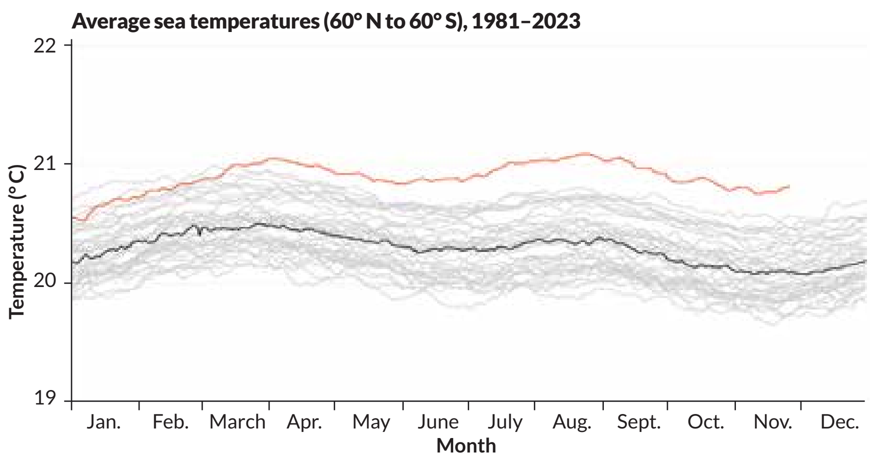
El Niño and other regional climate patterns probably played a role. Shifting ocean circulation or wind directions could have packed the ice in or shuttled it farther out to sea. But growing evidence suggests that warmer ocean waters may also be complicit, Serreze says.

Whatever the case, this year's trail of shattered records has made it clearer than ever that human-caused climate change is not a problem for tomorrow. "We're standing in the aftermath of one of the biggest waves in the climate system in recent history," Minor says, "and we need to also prepare for bigger waves that are approaching."

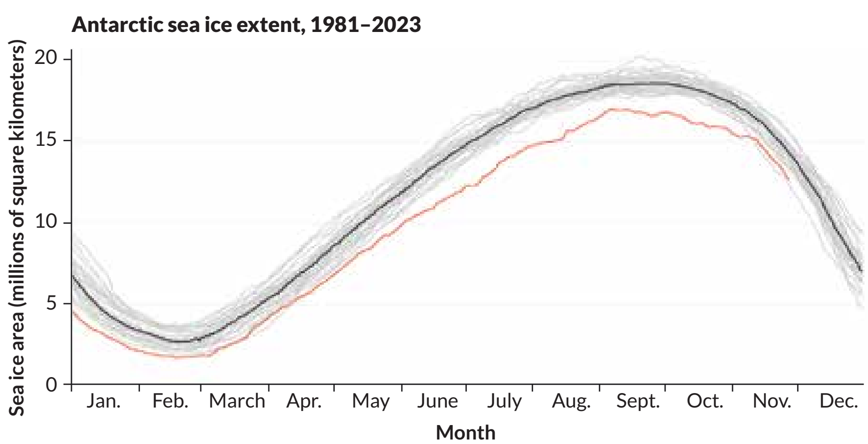
— Carolyn Gramling and Nikk Ogasa



Hot air The global average of daily air temperatures in 2023 (red) climbed to extraordinary heights during the Northern Hemisphere's summer months, soaring over global temperatures recorded each year since 1981 (gray). The 1981–2022 median air temperature is shown in black. SOURCE: CLIMATE REANALYZER/UNIV. OF MAINE



Sweltering seas Beginning in late March, 2023's average ocean surface temperatures (red) were higher for latitudes spanning 60° N to 60° S than in any year going back to at least 1981 (gray). The 1981–2022 median is shown in black. SOURCE: CLIMATE REANALYZER/UNIV. OF MAINE



Shrinking sea ice The expanse of sea ice surrounding Antarctica has remained at record-low levels for nearly all of 2023 (red), reaching its lowest point in February, the height of the Southern Hemisphere's summer. In September, when Antarctic sea ice typically reaches its largest extent, the sea ice was far below the 1981–2022 median (black). SOURCE: NSIDC

ALL: C. CROCKETT

Generative AI enters daily life

Ask ChatGPT "Why is the sky blue?" and seconds later, it will tell you: "The blue color of the sky is primarily due to a phenomenon called Rayleigh scattering," which the chatbot goes on to explain in a textbook-like, six-paragraph response. Follow up with, "Explain like I am 5 and make it short, please," and back will come: "The sky is blue because tiny things in the air make the blue light from the sun bounce around and come to our eyes."

ChatGPT is a type of generative AI. Its model taps into language patterns to predict the next words in a sentence, answering a user's prompt with a humanlike response. The model is structured with many layers of interconnected nodes, vaguely inspired by neural connections in the brain. During a training period, the interconnected nodes ran through billions of pieces of writing scraped from the internet, learning patterns by changing the strength of different node connections. Other types of generative AI have been trained to make images, videos and more.

Released late last year, ChatGPT quickly captivated public imagination, raising the visibility of generative AI. More chatbots, such as Google's Bard, followed. But amid the buzz, critics have warned of generative AI's inaccuracies, biases and plagiarism.

To understand how the technology came to dominate headlines and what's next, *Science News* spoke with Melanie Mitchell of the Santa Fe Institute, one of the world's leading AI experts. This interview has been edited for length and clarity.

Why was generative AI big this year?
We have had language models for many years. But the breakthrough with systems like ChatGPT is that they had much more training to be a dialog partner and assistant. They were trained on much more data. And they had many more connections, on the order of billions to trillions. They also were presented to the public with a very easy-to-use interface. Those things really were what made them take off, and people were just amazed at how humanlike they seemed.

Where do you think generative AI will have the greatest impact?
That's still a big open question. I can put in a prompt to ChatGPT, say please write an abstract for my paper that has these points in it, and it will spit out an abstract that's often pretty good. As an assistant, it is incredibly helpful. For generative images, systems can produce stock images. You can just say I need an image of a robot walking a dog, and it will generate that.

But these systems are not perfect. They make mistakes. They sometimes "hallucinate." If I ask ChatGPT to write an essay on some topic and also to include some citations, sometimes it will make up citations that don't exist. And it may also generate text that is just not true.



People are increasingly using chatbots that respond in humanlike ways.

LAURENCE DUTTON/E+/GETTY IMAGES PLUS

Are there other concerns?
They require a lot of energy. They run in giant data centers with huge numbers of computers that need a lot of electricity, that use a lot of water for cooling. So there is an environmental impact.

These systems have been trained on human language, and human society has a lot of biases that get reflected in the language these systems have absorbed — racial, gender and other demographic biases. There was an article recently that described how people were trying to get a text-image system to generate a picture of a Black doctor treating white children. And it was very hard to get it to generate that.

There are a lot of claims about these systems having certain capabilities in reasoning, like being able to solve math problems or pass standardized tests like the bar exam. We don't really have a sense of how they are doing this reasoning, whether that reasoning is robust. If you change the problem a little bit, will they still be able to solve it? It's unclear whether these systems can generalize beyond what they have been trained on or whether they are just relying very much on the training data. That's a big debate.

What do you think about the hype?
People have to be aware that AI is a field that tends to get hyped, ever since its beginning in the 1950s, and to be somewhat skeptical of claims. We have seen again and again that those claims are very much overblown.

These are not humans. Even though they seem humanlike, they are different in many ways. People should see them as a tool to augment our human intelligence, not replace it — and make sure there's a human in the loop rather than giving them too much autonomy.

What do you hope happens next?
We are in a bit of a state of uncertainty of what these systems are and what they can do, and how they will evolve. I hope that we figure out some reasonable regulation that mitigates possible harms but doesn't clamp down too hard on what could be a very beneficial technology. — *Ananya*

Sacred Stone of the Southwest is on the Brink of Extinction



Centuries ago, Persians, Tibetans and Mayans considered turquoise a gemstone of the heavens, believing the striking blue stones were sacred pieces of sky. Today, the rarest and most valuable turquoise is found in the American Southwest— but the future of the blue beauty is unclear.

On a recent trip to Tucson, we spoke with fourth generation turquoise traders who explained that less than five percent of turquoise mined worldwide can be set into jewelry and only about twenty mines in the Southwest supply gem-quality turquoise. Once a thriving industry, many Southwest mines have run dry and are now closed.



We found a limited supply of turquoise from Arizona and purchased it for our ***Sedona Turquoise Collection***. Inspired by the work of those ancient craftsmen and designed to showcase the exceptional blue stone, each stabilized vibrant cabochon features a unique, one-of-a-kind matrix surrounded in Bali metalwork. You could drop over $1,200 on a turquoise pendant, or you could secure 26 carats of genuine Arizona turquoise for **just $99**.

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Superconductor highs and lows

With bold claims of creating revolutionary room-temperature superconductors, physicist Ranga Dias of the University of Rochester in New York propelled the field of high-pressure physics into the spotlight in recent years.

Now, after scientific journals have retracted three of his papers, including two this year, a haze of suspicion surrounds Dias, and some physicists worry that outsiders might suspect the entire field is in disarray. "The big risk is that this whole thing... sheds a negative light on this field," says theoretical physicist Lilia Boeri of the Sapienza University of Rome.

But other research on high-temperature superconductors is solid, many physicists say. Multiple groups have replicated key results, and theoretical calculations agree with real-world experiments. Physicists are investigating new classes of superconductors and confirming predictions. The hope is that such advances eventually lead to a more practical superconductor.

"The sad thing is that there is a lot of nice work going on in the field but this [controversy] has taken so much attention," Boeri says.

To shore up the legitimacy of claims, scientists are developing new ways to identify superconductivity, debating what standards should be met before one can claim to have achieved superconductivity, and discussing new norms around sharing data.

The work could help stave off future questionable claims. "We all recognize that our field is in danger of being written off by the wider scientific community because of all of the false positives," says theoretical physicist Peter Hirschfeld of the University of Florida in Gainesville.

Growing controversy

With the power to conduct electricity without resistance, superconductors have already found some use in specialized technologies, such as MRI magnets and quantum computers. But if they can be made to function at temperatures and pressures fit for everyday use, they could transform modern technology, for example, enabling an electric grid free from energy loss. This tantalizing possibility fuels hype to levels uncommon in the typically esoteric realm of physics research.

The first eye-popping superconductivity claim from Dias' group came in 2020. Most superconductors must be cooled to very low temperatures to function, but a material of carbon, sulfur and hydrogen remained superconducting at up to 15° Celsius (59° Fahrenheit), the group reported in *Nature* (*SN: 11/7/20, p. 6*).

That material, like many of the highest-temperature superconductors, had to be squeezed to high pressure, so it was not feasible for practical use. Still, it was purportedly the first demonstration of a long-sought room-temperature superconductor. But after other scientists raised doubts, *Nature* retracted the paper in September 2022.

In March, Dias' team countered with an even bigger claim (*SN: 3/25/23, p. 6*). A material made of lutetium, nitrogen and hydrogen superconducts at room temperature and under pressures much closer to atmospheric pressure, the team reported in *Nature*.

Some physicists worry outsiders might suspect the entire field is in disarray.

Meanwhile, skeptics delved into Dias' history, alleging plagiarism in his Ph.D. thesis, according to an analysis reported in *Science*. The digging also flagged a 2021 paper coauthored by Dias in *Physical Review Letters*, or *PRL*, unrelated to the *Nature* papers. An investigation by *PRL* found evidence of data fabrication, *Nature* reported in July. With the agreement of all the authors but Dias, *PRL* retracted the paper.

Then in November, *Nature* retracted the lutetium superconductor paper at the request of eight of the paper's 11 coauthors, stating that "the published paper does not accurately reflect the provenance of the investigated materials, the experimental measurements undertaken and the data-processing protocols applied."

Asked about the retraction, Dias provided a statement that reads, in part: "Ranga Dias refutes any allegations of research misconduct and remains steadfast in supporting all the scientific conclusions presented in the paper." Dias is now under investigation by the University of Rochester, a university spokesperson says.

Reproducibility reigns

High-pressure physics is highly specialized, and experiments that succeed in one lab can be challenging to replicate elsewhere. But in the last decade, progress has been made in creating superconductors that require less chilling.

The research centers on hydrogen-rich materials called hydrides. This choice was inspired by a prediction that pure hydrogen would become a superconducting metal when squeezed to extreme pressure. Because those pressures proved difficult to reach, scientists added in other elements in hopes of lowering the pressure.

The first major success came in 2015 when a compound of sulfur and hydrogen broke the record for the highest-temperature superconductor at the time (*SN: 12/26/15, p. 25*). It superconducts up to around 203 kelvins (–70° C), physicist Mikhail Eremets of the Max Planck Institute for Chemistry in Mainz, Germany, and colleagues reported. In 2018, scientists crowned the current record holder (apart from Dias' work), a compound of lanthanum and hydrogen, which superconducts up to about –20° C (*SN: 10/13/18, p. 6*).

In both cases, multiple groups have confirmed the results. And theoretical calculations agree that the materials are superconducting at these high temperatures. But both superconductors require a squeeze more than a million times the pressure of Earth's atmosphere.

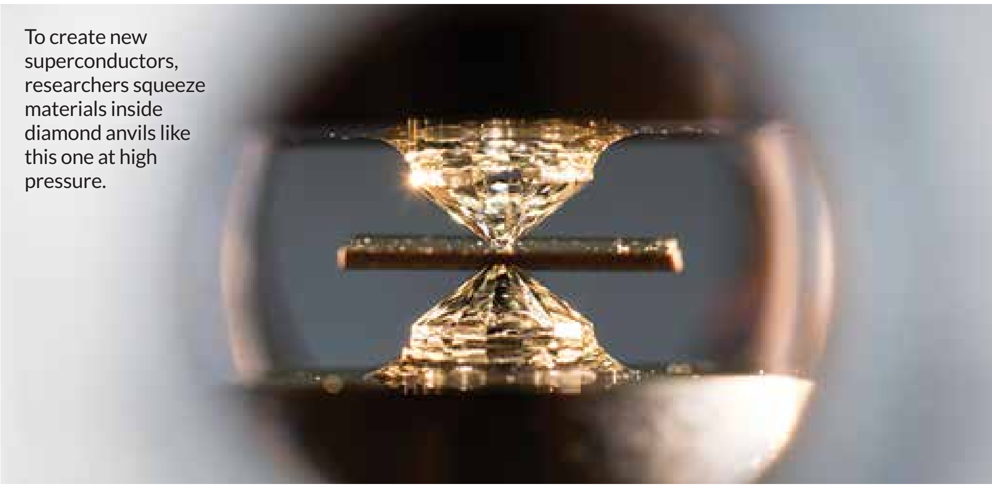
In contrast, physicists have struggled to conclusively reproduce the Dias group's lutetium superconductor, or to come up with a convincing theoretical explanation for it. Coupled with the retractions, that leaves many researchers doubtful. "I absolutely do not trust any results of this group," says physicist Dmitrii Semenok of

the Center for High Pressure Science & Technology Advanced Research in Beijing.

In an email to *Science News* after the second retraction, Dias waved away concerns, writing that "if people are struggling to replicate my work, that's not surprising—not everyone will be able to do what took me years to accomplish."

At least one researcher believes in the work. Materials chemist Russell Hemley of the University of Illinois Chicago, who was part of a team that discovered the lanthanum hydride superconductor, was one of the few scientists to claim a confirmation of Dias' lutetium result, using a sample created in collaboration with Dias' group.

"Our own measurements on the material, carried out independently in our lab, show the same signatures of very high-temperature superconductivity that we found for the lanthanum hydride," Hemley says. While other researchers have questioned whether the Hemley group's reported results convincingly confirm superconductivity, Hemley defends the findings, saying he is confident that other groups will eventually replicate the result.



To create new superconductors, researchers squeeze materials inside diamond anvils like this one at high pressure.

J. ADAM FENSTER/UNIV. OF ROCHESTER

New materials debut

In light of the retractions and failed replications, many physicists say other developments are more worthy of attention.

One hot topic is ternary hydrides, materials that combine hydrogen with two additional elements instead of just one. In *PRL* in June, scientists reported the first example of a ternary hydride with a structure of atoms not seen in previous binary hydrides. Made of lanthanum, beryllium and hydrogen, the material is superconducting up to about 100 kelvins (about −173° C). That's not a record by any means. But it requires less pressure than some other hydrides, says physicist Yanming Ma of Jilin University in Changchun, China. "We have the first example. Then later on, maybe people [will] build on our work."

In another development, physicists tied up a loose end. A superconductor predicted in 2012, calcium hydride, was finally produced, two teams reported last year. This was the first hydride superconductor predicted with a "clathrate" structure, in which the hydrogen atoms form a cage around another type of atom.

This structure has since been found in other high-temperature superconductors. Finding calcium hydride is "a nice success," says theoretical physicist Eva Zurek of the University at Buffalo in New York. "Examples like this go counter to saying … that the whole field is doing crappy work."

Some physicists are going beyond hydrogen. Timothy Strobel of the Carnegie Institution for Science in Washington, D.C., is swapping in other light elements. He's studying clathrates made with boron and carbon. "We would expect moderately high-temperature superconductivity, but not as high as hydrogen," Strobel says.

But that trade-off may be worth it. With such materials, scientists hope to find structures sturdy enough to persist at atmospheric pressure. It's similar to diamond, which forms under pressure but remains intact once that pressure is released. Last January in the *Journal of the American Chemical Society*, Zurek, Strobel and colleagues predicted that some of these materials could be superconductors at up to 88 kelvins (about −185° C) under atmospheric pressure.

That might seem low in comparison to the hydrides. But temperatures above 77 kelvins (about −196° C), the boiling point of liquid nitrogen, are more easily achievable in practical use, because costly liquid helium isn't required for coolant. In contrast, high pressures are currently prohibitive for practical purposes. Ambient pressure may be more important than room temperature, Strobel argues.

Raising the bar

In parallel to investigating new superconductors, high-pressure physicists are also discussing how to avoid controversies in the future. Some physicists are calling for more sharing of raw data to make it easier to check claims and replicate experiments.

Physicists also want to strengthen the evidence for superconductivity. It's not all about electrical resistance. Another telltale sign is the Meissner effect, in which a material expels magnetic fields. This and other effects can help confirm superconductivity. But that's difficult to do in experiments that involve mere specks of material squeezed between two diamonds.

So scientists are coming up with additional types of confirmation. For example, when certain superconductors are exposed to a magnetic field and the magnetic field is later switched off, a residual magnetic field remains trapped within the superconductor. In *Nature Physics* in June, Eremets and colleagues reported measurements of trapped magnetic fields in both the sulfur and lanthanum hydrides.

Another effort in the works is setting standard criteria to meet before claiming a superconductor discovery.

Even with these efforts, spurious claims will probably be challenging to eliminate. "It's not something rare; it happens from time to time," Semenok says. Case in point: A purported room-temperature, ambient-pressure superconductor reported at arXiv.org in July before peer review went viral on social media. Further investigation soon debunked the claim. *—Emily Conover*

Eyebrow-raising claims

From ancient cannibalism to stars made of dark matter, 2023 delivered some scientific claims that could shake up their fields — if they shape up to be true.

Butchered bone

Purported tool marks on a 1.45-million-year-old fossilized leg offer the oldest evidence of cannibalism among humans' ancient relatives, researchers contend (SN: 8/12/23, *p.* 10). The marks on the bone, found in Kenya, could have been made by some unidentified hominid using a stone tool to carve muscle away from the shin of another hominid. But a few bone nicks do not cannibal table scraps make, some paleoanthropologists say.

Overgrown galaxies

A handful of galaxies from the very early universe are up to 100 times as massive as expected, data from NASA's James Webb Space Telescope suggest (SN: 3/25/23, *p.* 14). The hefty galaxies not only challenge the idea that matter clumped together slowly over the universe's lifetime, but also hint at some unknown way to fast-track galaxy formation. But the galaxies' weights and distances must be confirmed with more detailed analyses of their light before astronomers rewrite cosmic history.

Spark of life

Early life on Earth may have gotten a boost from giant volcanic eruptions. A new look at debris from 10 eruptions millions of years ago suggests they contained a lot of nitrate that formed in the atmosphere (SN: 6/3/23, *p.* 7). The eruptions could have triggered fierce lightning that ripped apart molecular nitrogen, freeing nitrogen atoms to bond with other elements and form molecules useful to life, including nitrate. The same process may have happened billions of years ago, some scientists say, producing ingredients for early life. Scientists will need to account for the different chemical makeup of primordial Earth's atmosphere to bolster that claim.

Thymus rethink

The thymus may not be inconsequential for adult health after all (SN: 8/26/23, *p.* 7). This immune system organ between the lungs is most active in childhood and withers with age, so it's often considered expendable in adulthood. In a study of more than 2,000 adults who had chest surgery, however, researchers reported that removing the thymus gland was associated with higher rates of death and of cancer within the next few years. Why thymus removal might be harmful remains unclear.



Volcanic eruptions can generate a lot of lightning. Some scientists argue that on early Earth, such lightning made crucial ingredients for life.

Dead and buried?

Honoring the dead may not be unique to big-brained hominids like *Homo sapiens* and Neandertals. *Homo naledi*, which lived around the same time as early *H. sapiens* but had an orange-sized brain, intentionally buried bodies in an underground South African cave, a group of researchers claims (SN: 7/1/23, *p.* 6). Other experts remain unconvinced, though. The supposedly buried bodies, which predate the earliest evidence of *H. sapiens* and Neandertal burials by 160,000 years — could have fallen through cave shafts or been washed by water into natural depressions in cave floors, skeptics say.

Rocked to the core

Separate studies both based on earthquake data are shaking up geologists' concept of Earth's heart. The solid inner core not only rotates but also appears to switch the direction of rotation relative to the mantle and crust every few decades (SN: 2/25/23, *p.* 7). The inner core may also have a secret chamber (SN: 4/8/23, *p.* 17). Other data, however, hint that the inner core reverses every few years or does not rotate at all. And the supposed discovery of the innermost core hinges on a type of seismic wave that bounces around Earth's interior, becoming weaker and more difficult to detect with every bounce. Thankfully, whatever is going on down there does not seem to endanger life on the surface.

Dark matter stars

The James Webb Space Telescope may have spotted stars made of dark matter — the unidentified stuff that makes up most matter in the cosmos (SN: 8/26/23, *p.* 8). So-called dark stars are so far hypothetical, but JWST observed three objects giving off the kind of light expected from such stars. If they exist, dark stars could shed new light on star formation and the nature of dark matter. However, the pinpricks of light in JWST's field of view could also come from normal stars, so astronomers will need more detailed data to tease out the objects' true nature. *— Maria Temming*

MARTIN BERNETTI/AFP VIA GETTY IMAGES

Weight-loss drugs go mainstream

This year, celebrity gossip, a national shortage and eyebrow-raising clinical trials made household names of weight-loss and diabetes drugs like Ozempic, Wegovy and Mounjaro.

The buzzy drugs belong to a class of powerful medications that can manage blood sugar levels and drastically reduce body weight — a hot property that kicked them into the mainstream. This spring, even WeightWatchers got on board, acquiring a virtual clinic that offers prescriptions for the popular drugs.

The medications' ever-expanding reach might explain why many people in the United States are having trouble filling prescriptions. From 2020 to 2022, the number of prescriptions for these drugs quadrupled — up to roughly 9 million in the final months of 2022, according to one analysis. In 2023, the U.S. Food and Drug Administration included both Ozempic and Wegovy on its drug shortages list.

And demand may continue to rocket up. Data from clinical trials and other studies suggest these drugs can improve cardiovascular health and perhaps even help treat addiction (SN *Online*: 8/30/23).

The FDA approved Ozempic for type 2 diabetes in 2017, and now new, potentially more potent and easier-to-produce versions are in the pipeline, says Susan Yanovski, a physician and nutrition specialist at the National Institute of Diabetes and Digestive and Kidney Diseases in Bethesda, Md. "I've been doing this for more than 30 years now, and I have not seen this degree of excitement."

It's the first time doctors have had obesity drugs that work so well, she says, approaching weight-loss levels previously seen only with bariatric surgery. But, Yanovski cautions, "it's still early days."

Amid the hubbub, a fresh influx of clinical trial data has opened a Pandora's box of questions. How exactly do the drugs work? Who should take them? For how long? What's the full range of side effects? "We've got a lot of research to do," Yanovski says.

A powerful class of drugs

Ozempic is the brand name for the drug semaglutide; Wegovy, also semaglutide, has a higher maximum dose and is approved for weight loss. Semaglutide mimics a gut hormone, GLP-1, that's secreted after people eat. When given a high dose weekly, people without diabetes can lose about 15 percent of their body weight, on average, after nearly 16 months. Scientists think the drug acts on the body and the brain, making people feel full and muffling food cravings.

Yet semaglutide may have an even more dramatic action — saving lives, scientists suggested November 11 in Philadelphia at the American Heart Association meeting. Weekly injections of the drug lowered the risk of heart attacks, strokes and death due to cardiovascular disease in some adults, Cleveland Clinic cardiologist A. Michael Lincoff reported. The trial targeted people who are overweight or obese who have high cardiovascular risk but not diabetes.

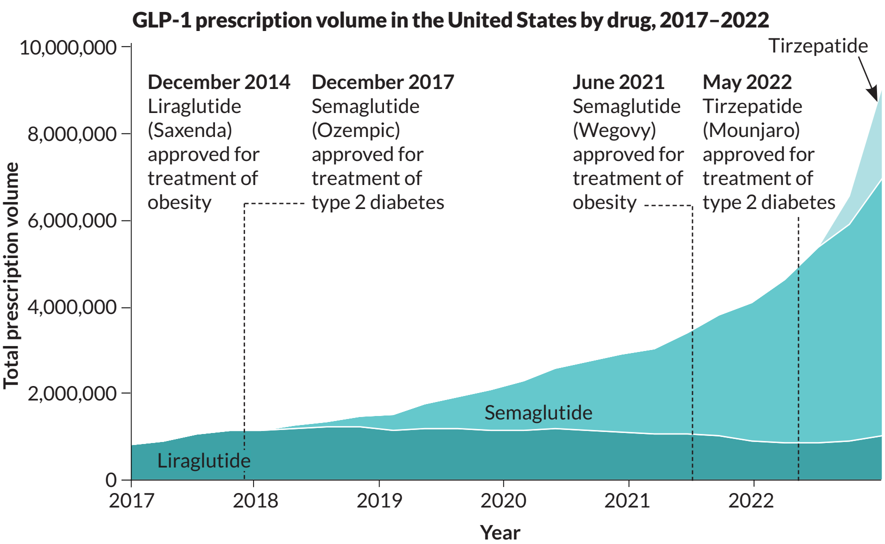
That's important because it wasn't clear until now that these patients would see heart benefits, says Tiffany Powell-Wiley, a cardiologist and epidemiologist at the National Heart, Lung and Blood Institute in Bethesda. The find "really opens up the number of patients that we can treat with semaglutide," she says. Powell-Wiley notes, though, that obesity is a complex disease with many causes that no single drug — even a powerful one — can fix.

Still, pharmaceutical companies are racing to investigate new, improved relatives of semaglutide. Some of these drugs mimic multiple gut hormones rather than just one. One such molecule, tirzepatide (brand name Mounjaro), mimics both GLP-1 and the gut hormone GIP. The FDA approved tirzepatide for treating type 2 diabetes last year and for treating obesity in November, under the brand name Zepbound. The drug seems to cause even more weight loss than semaglutide, Yanovski says.

Another drug in development could one-up even tirzepatide. Retatrutide simulates three gut hormones: GLP-1, GIP and glucagon. People treated with a high dose lost an average of 24 percent of their body weight after nearly a year of treatment, a small clinical trial reported this year.

The full roster of these drugs, what they do and where they stand in the approval process makes for a dizzying array of information. But an assortment of options may pay off, Yanovski says. "We really need a variety of drugs … so that we can match the right treatment to the right patient."

In demand Over the last few years, prescriptions for a class of drugs that can lower blood sugar levels and body weight have skyrocketed in the United States. Semaglutide and a related drug called liraglutide both mimic the gut hormone GLP-1. Tirzepatide mimics GLP-1 plus a second gut hormone, GIP. SOURCE: TRILLIANT HEALTH 2023



T. TIBBITTS

Weighing the risks and benefits

But like any medication, Yanovski cautions, these drugs come with side effects. Semaglutide can cause nausea, diarrhea, vomiting, stomachache and constipation, among other ailments. Large amounts of rapid weight loss can also spur gallbladder disease, a complication sometimes seen after bariatric surgery. And these medications aren't melting away only fat. When people rapidly lose lots of weight, they can also lose muscle mass, a particular concern for older patients, Yanovski says.

As these drugs roll out into larger populations of people, rare side effects not seen in clinical trials will also emerge. One recent study found that people using semaglutide or a related drug for weight loss had an increased risk of serious gastrointestinal conditions, including inflammation of the pancreas and bowel blockages, compared with people using a different type of weight-loss drug.

And patients will probably need to take these medications long term or risk gaining the weight back. "This is not a flaw in the medications; this is how medications work," Yanovski says. If you stop taking cholesterol-lowering meds, for instance, your cholesterol may shoot up.

But the drugs' high cost (Wegovy's list price is about $1,350 per month and insurance coverage varies) puts even short-term use out of reach for many people. The cost can exacerbate health disparities and drive people to hunt for altered versions on the internet. Though these drugs may be cheaper, Yanovski says, they're not FDA-approved and could be counterfeit.

She hopes to see people with obesity, particularly those with medical complications, gain better access to the approved drugs and in settings where they can be monitored by their doctors to ensure that the benefits outweigh the risks.

Those without a true need for the drugs probably should avoid them, Yanovski says. They're "serious medications for a serious disease," she says. "I think the buzz that these are some kind of miracle cure for obesity, or that you should take these medications just because you want to lose that stubborn 10 pounds, is overhyped." *— Meghan Rosen*

New additions to the medicine cabinet

Weight-loss drugs stole the spotlight in 2023, but these treatment advances for other conditions are also worthy of attention.

Green light for gene editing

In November, the United Kingdom approved the world's first CRISPR/Cas9 gene-editing therapy. The treatment targets the blood disorders sickle cell disease and beta-thalassemia by helping patients produce hemoglobin. U.S. approval of the therapy as a treatment for sickle cell disease was expected to come in December.

Slowing down Alzheimer's

The Alzheimer's drug lecanemab (brand name Leqembi) won full approval from the U.S. Food and Drug Administration in July. Like the drug aducanumab approved in 2021, lecanemab removes the amyloid plaques that build up in the brains of people with Alzheimer's. The drug doesn't stop the disease, but in a clinical trial, lecanemab slowed cognitive decline by about 30 percent over 18 months compared with a placebo (*SN: 8/12/23, p. 9*).

A gene therapy for muscular dystrophy

In June, the FDA approved the first gene therapy for children with Duchenne muscular dystrophy. Due to a faulty gene, people with this muscle-wasting disease don't make the protein dystrophin, which helps keep muscle cells intact. The therapy helps the body produce a version of the missing protein (*SN Online: 6/22/23*).

Guarding against RSV

Several ways to protect against respiratory syncytial virus arrived this year. In May, the FDA approved the first RSV vaccine in the United States, for adults ages 60 and older (*SN: 6/17/23, p. 8*), and then in August, a vaccine for pregnant people (*SN Online: 8/25/23*). A monoclonal antibody — a lab-made antibody that mimics immune system proteins — won approval in July to protect young children 2 and younger from the virus (*SN Online: 4/27/23*). But in October, limited supplies of the therapy led the U.S. Centers for Disease Control and Prevention to recommend reserving it for babies at highest risk for complications from RSV.

A pill for postpartum depression

Until August, the only medication in the United States specifically targeting postpartum depression required a 60-hour intravenous infusion in a hospital. With FDA approval of zuranolone (brand name Zurzuvae), those afflicted with postpartum depression can take an oral medication at home.

Birth control, no prescription required

In July, the FDA ruled that the oral contraceptive norgestrel, first approved in 1973, be available without a prescription. It's the first OTC daily birth control pill in the United States. Some public health experts argue that reducing barriers to contraception is especially important to reproductive autonomy now that state bans have limited access to abortion (*SN Online: 5/19/23*).

A shot against chikungunya

The chikungunya virus can cause fever and severe joint pain, and be fatal to newborns. In November, the FDA approved the first vaccine against the virus, which is transmitted by mosquitoes. The virus is most prevalent in tropical regions, but the FDA warns that it's spreading to new parts of the globe. *— Erin Wayman*

COVID-19's next chapter

This month marks the fourth anniversary of COVID-19. It was in December 2019 that doctors in Wuhan, China, identified the first known case. Just a few months later, the coronavirus had spawned a pandemic.

Today, the worst of the pandemic is largely behind us. Most infections with SARS-CoV-2, the virus that causes COVID-19, are now less deadly than they were during the pandemic's early days, thanks to more widespread immunity. As of last year, about 96 percent of people in the United States had been vaccinated, infected with the virus or both, data suggest. In mid-September, updated shots rolled out to boost our immune defenses.

Even with these rays of hope, our future with SARS-CoV-2 is unclear. The virus is still spreading, but it's harder to get a good grasp of the start of surges or know what's happening within communities. That's in part because labs are no longer required to report new cases to the U.S. Centers for Disease Control and Prevention, one of the outcomes of the nationwide public health emergency ending in May.

One big question is when will COVID-19 become endemic, circulating in a more predictable pattern year to year. And an even bigger question: When we reach that stage, how many people will fall ill or die on average each year?

Science News spoke with epidemiologist Aubree Gordon of the University of Michigan in Ann Arbor to learn more about this year's COVID-19 trends and the disease's next phase. The conversation has been edited for length and clarity.



The worst of the COVID-19 pandemic in the United States and the days of social distancing may be over, thanks to widespread immunity.

How are things different now than in previous years?

Pretty much everybody [in the United States] has some sort of immunity against SARS-CoV-2. A majority of people have hybrid immunity, meaning they have been not only vaccinated but had an infection. For unvaccinated people, most have been infected a few times. And some vaccinated people have been infected a few times. That doesn't prevent reinfection, but it certainly helps to reduce the severity of infections.

How important is the updated shot?

Updated shots are definitely advised, particularly for individuals at risk for severe disease. I had hoped that we would have arrived at a point where SARS-CoV-2 was looking like a seasonal coronavirus, causing symptoms of the common cold, and was therefore less severe than influenza. But SARS-CoV-2 is still more severe than flu.

Vaccination alone, while clearly protective against hospitalization and death, hasn't broadened the immune response [to recognize many viral variants] like vaccination plus subsequent infections has. That appears to be the case with last year's bivalent shot [that targeted both the original virus and the omicron variant]. Our bodies were biased to build immunity against the original virus [which most people had already been exposed to via infection or previous vaccination].

The U.S. Food and Drug Administration recommended removing the original virus from the shot this year and focusing only on [the once-dominant] variant [XBB.1.5]. The big question is whether this new vaccine will broaden immunity like infection does. If that occurs, and enough people get the vaccine, that would be a game changer.

Where are we on the spectrum between pandemic and endemic?

We're getting close to endemic. I don't know if we'll be at that level for this next [COVID-19] season, or another season or two. But [disease severity] has been trending downward over the last many months. The hope is we continue to see that downward trend. If [COVID-19] had hit its endemic level, we would expect some season-to-season fluctuations, but it'd be fluctuating around that number rather than continuing a downward trend of being less and less severe.

I'm kind of hoping we're not at the endemic level yet. At least based on last year, because there were a substantial number of deaths in the United States — 244,000 was the CDC estimate. It's four or five times higher than a severe seasonal influenza season.

What might endemic look like?

It's become clear that this is going to be a regular infection that people may get more often than flu. Maybe the virus will start changing less. For adults, it looks like it's going to [be as dangerous as] influenza if not more. I had thought that everybody would need maybe a vaccination and then one or two infections to get at the endemic level. It's possible that you need a little bit broader immunity [to protect against new variants] and more exposures to hit that level.

What will we learn going forward?

One thing that we'll look at this winter is how different it is from last winter. If we're still seeing a downward trajectory, then maybe we haven't yet hit the endemic level. Or we may see something that looks quite similar to last year, which would tell us that perhaps we've arrived.

There is season-to-season variability, there are differences in variants, and we have new variants arising, which will all contribute on a yearly basis to how severe the SARS-CoV-2 season is. We have that for flu. CDC estimates for recent flu seasons, excluding the pandemic ones, were anywhere from 12,000 to 52,000 deaths a year. That's quite a bit of variability.
— Erin Garcia de Jesús

RICHARD LEVINE/ALAMY

Hunting for new ways to snag gravitational waves

Until recently, gravitational waves could have been a figment of Einstein's imagination. Before they were detected, these ripples in spacetime existed only in the physicist's general theory of relativity, as far as scientists knew.

Now, researchers have not one but two ways to detect the waves. And they're on the hunt for more. The study of gravitational waves is booming, says Karan Jani, an astrophysicist at Vanderbilt University in Nashville. "This is just remarkable. No field I can think of in fundamental physics has seen progress this fast."

Just as light comes in a spectrum, or a variety of wavelengths, so do gravitational waves. Different wavelengths point to different types of cosmic origins and require different flavors of detectors.

Gravitational waves with wavelengths of a few thousand kilometers — like those detected by LIGO in the United States and its partner Virgo in Italy — come mostly from merging pairs of black holes 10 or so times the mass of the sun, or from collisions of dense cosmic nuggets called neutron stars. These detectors could also spot waves from certain types of supernovas — exploding stars — and from rapidly rotating neutron stars called pulsars.

In contrast, immense ripples with wavelengths that span light-years are thought to be created by orbiting pairs of whopper black holes with masses billions of times that of the sun. In June, scientists reported the first strong evidence for these types of waves by using the entire galaxy as a detector, watching how the waves tweaked the timing of regular blinks from pulsars scattered throughout the Milky Way (*SN: 8/12/23, p. 12*).

With the equivalent of both small ripples and major tsunamis in hand, physicists now hope to plunge into a vast, cosmic ocean of gravitational waves of all sorts of sizes. These ripples could reveal new details about the secret lives of exotic objects such as black holes and about unknown facets of the cosmos.

"There's still a lot of gaps in our coverage of the gravitational wave spectrum," says physicist Jason Hogan of Stanford University. But it makes sense to cover all the bases, he says. "Who knows what else we might find?"

This quest to capture the full complement of the universe's gravitational waves could take observatories out into deep space or the moon, to the atomic realm and elsewhere. Here's a sampling of some of the frontiers scientists are eyeing in search of new types of waves.

Go to deep space

The Laser Interferometer Space Antenna, or LISA, sounds implausible at first. A trio of spacecraft, arranged in a triangle with 2.5-million-kilometer sides, would beam lasers to one another while cartwheeling in an orbit around the sun. But the European Space Agency mission, planned for the mid-2030s, is no fantasy. It is many scientists' best hope for breaking into new realms of gravitational waves.

"LISA is a mind-blowing experiment," says theoretical physicist Diego Blas Temiño of Universitat Autònoma de Barcelona and Institut de Física d'Altes Energies.

As a gravitational wave passes by, LISA would detect the stretching and squeezing of the sides of the triangle, based on how the laser beams interfere with each other at the triangle's corners. A proof-of-concept experiment with a single spacecraft, LISA Pathfinder, flew in 2015 and demonstrated the feasibility of the technique.



The Laser Interferometer Space Antenna, or LISA, will be made up of a trio of spacecraft orbiting the sun (illustrated in foreground). LISA will observe gravitational waves from orbiting supermassive black holes in distant galaxies (one illustrated in background).

SIMON BARKE/UNIV. OF FLORIDA (CC BY 4.0)

Generally, to catch longer wavelengths of gravitational waves, you need a bigger detector. LISA would let scientists see wavelengths millions to billions of kilometers long. That means LISA could detect orbiting black holes that would be enormous, but moderately so — millions of times the mass of the sun instead of billions.

Go to the moon

With NASA's Artemis program aiming at a return to the moon, scientists are looking to Earth's neighbor for inspiration. A proposed experiment called the Laser Interferometer Lunar Antenna, or LILA, would put a gravitational wave detector on the moon.

Without the jostling of human activity and other earthly jitters, gravitational waves should be easier to pick out on the moon. "It's almost like a spiritual quietness," Jani says. "If you want to listen to the sounds of the universe, there is no place better in the solar system than our moon."

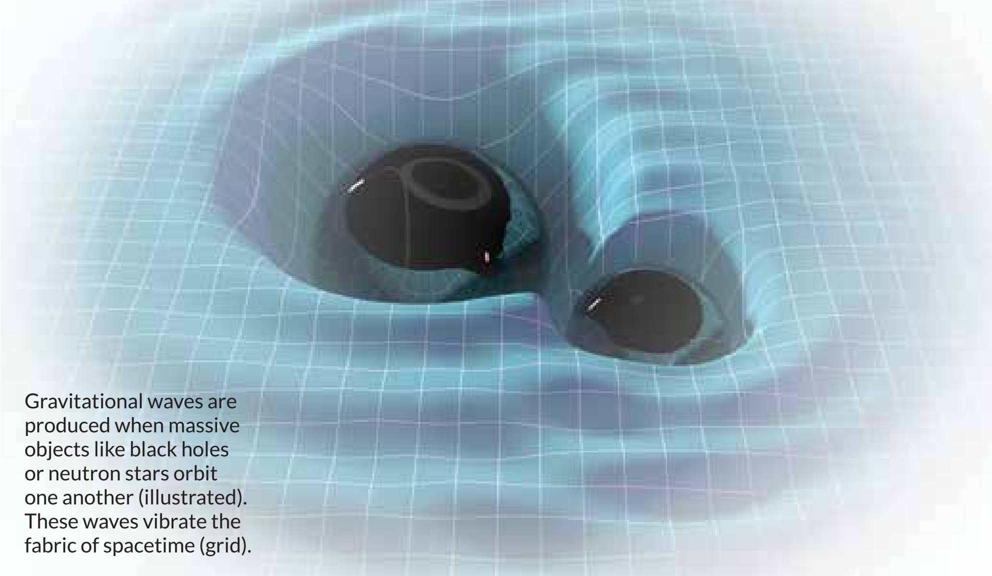
Like LISA, LILA would have three stations beaming lasers in a triangle, though the sides of this one would be about 10 kilometers long. It could catch wavelengths tens or hundreds of thousands of kilometers long. That would fill in a gap between the wavelengths measured by the space-based LISA and the Earth-based LIGO.

Because orbiting objects like black holes speed up as they get closer to merging, over time they emit gravitational waves with shorter and shorter wavelengths. That means LILA could watch black holes close in on one another during the weeks before they merge, giving scientists a heads-up that a collision is about to go down. Then, once the wavelengths get short enough, earthly observatories like LIGO would pick up the signal, catching the moment of impact.

A different moon-based option would use lunar laser ranging — a technique by

which scientists measure the distance from Earth to the moon by bouncing lasers off reflectors on the moon's surface.

The method could detect waves jostling Earth and the moon, with wavelengths in between those seen by pulsar timing methods and LISA, Blas Temiño and a colleague reported in *Physical Review D* in 2022. But that technique would require an upgrade to reflectors placed on the moon during previous moon landings — another reason to go back.



Gravitational waves are produced when massive objects like black holes or neutron stars orbit one another (illustrated). These waves vibrate the fabric of spacetime (grid).

MARK GARLICK/SCIENCE PHOTO LIBRARY/GETTY IMAGES PLUS

Go atomic

LISA, LIGO and other laser observatories measure the stretching and squeezing of gravitational waves by monitoring how laser beams interfere after traversing their detectors' long arms. But a proposed technique goes a different route.

Rather than looking for slight changes in the lengths of detector arms as gravitational waves pass, this technique would keep an eye on the distance between two clouds of atoms. The quantum properties of atoms mean that they act like waves that can interfere with themselves. If a gravitational wave passes through, it would change the distance between the atom clouds. Scientists could tease out that change in distance based on that quantum interference.

The technique could reveal gravitational waves with wavelengths between those detectable by LIGO and LISA, Hogan says. He's part of an effort to build a prototype detector, called MAGIS-100, at Fermilab in Batavia, Ill.

Atom interferometers have never been used to measure gravitational waves, though they can sense Earth's gravity and test fundamental physics rules. The idea is "totally futuristic," Blas Temiño says.

Go back in time

Another effort aims to pinpoint gravitational waves from the earliest moments of the universe. Such waves would have been produced during inflation, the moments after the Big Bang when the universe ballooned in size. These waves would have longer wavelengths than ever seen before — as long as 10^{21} kilometers, or 1 sextillion kilometers.

But the hunt got off to a false start in 2014, when scientists with the BICEP2 experiment proclaimed the detection of gravitational waves imprinted in swirling patterns on the oldest light in the universe, the cosmic microwave background, or CMB. The claim was later overturned.

An effort called CMB-Stage 4 will continue the search, with plans for multiple new telescopes that would scour the universe's oldest light for signs of the waves — this time, hopefully, without any missteps.

Go for the unknown

For most types of gravitational waves that scientists have set their sights on, they know a bit about what to expect. Known objects — like black holes or neutron stars — can create those waves.

But for gravitational waves with the shortest wavelengths, perhaps just centimeters long, "the story is different," says theoretical physicist Valerie Domcke of CERN near Geneva. "We have no known source … that would actually give us [these] gravitational waves of a large enough amplitude that we could realistically detect them."

Still, physicists want to check if the tiny waves are out there. These ripples could be produced by violent events early in the universe's history such as phase transitions, in which the cosmos converts from one state to another, akin to water condensing from steam into liquid. Another possibility is tiny, primordial black holes, too small to be formed by standard means, which might have been born in the early universe. Physics in these regimes is so poorly understood, "even looking for [gravitational waves] and not finding them would tell us something," Domcke says.

These potential gravitational waves are so mysterious that their detection techniques are also up in the air. But the wavelengths are small enough that they could be seen with high-precision, lab-scale experiments rather than giant detectors.

Scientists might even be able to repurpose data from experiments designed with other goals in mind. When gravitational waves encounter electromagnetic fields, the ripples can behave in ways similar to hypothetical subatomic particles called axions. So experiments searching for those particles might also reveal mini gravitational waves.

A new view

Catching gravitational waves is like paddling against the tide: tough going, but worth it for the scenic views. It took decades of work before LIGO spotted its first swells, and the same is true of the pulsar timing technique. But the rewards were immediate. "It's a whole new view of the universe," Hogan says.

Already, gravitational waves have helped confirm Einstein's general theory of relativity, discover a new class of black holes of moderately sized masses and unmask the fireworks that happen when two neutron stars collide.

And it's still early days. Scientists can only guess at what future detectors will expose. "There's way more to discover," Hogan says. "It's bound to be interesting." — *Emily Conover*

Science firsts

Science experienced many first-of-a-kind feats this year. These are the groundbreaking achievements that grabbed our attention.

Hats off

After more than 50 years of searching, mathematicians finally found an einstein tile (*ein Stein* is German for "one stone"). The shape, dubbed "the hat," fits with its mirror image to create an infinite pattern that never repeats (SN: 4/22/23, *p.* 7). Soon after, researchers discovered a "vampire" einstein, a shape that doesn't require its mirror image to create an infinite nonrepeating pattern (SN: 7/1/23, *p.* 9). Einstein tiles and their unique balance between order and disorder could spur new discoveries in materials science.

Fleeting debut

The first appearance of oxygen-28, a superheavy form of the element that physicists created in a particle accelerator, was much briefer than researchers had expected (SN: 10/7/23 & 10/21/23, *p.* 4). The isotope decayed almost immediately after forming, despite its atomic nucleus having full outer shells of protons and neutrons — a property that is typically linked with extra stability. Oxygen-28's instability hints that something may be wrong with our understanding of the strong nuclear force, which binds protons and neutrons.

RNA retrieval

Scientists isolated and decoded RNA from an extinct creature for the first time. The fragile molecules, which help ensure that cells follow their DNA instruction manuals, were extracted from a preserved Tasmanian tiger held in a museum (SN: 11/4/23, *p.* 10). Researchers hope that the feat will aid efforts to bring back the wolflike marsupial, which is named after its homeland and died out in 1936.

Surviving a deep freeze

Adult corals can be safely flash-frozen and revived, researchers demonstrated, raising hopes that cryopreservation could be useful in coral conservation (SN: 9/23/23, *p.* 11). The key to preventing ice crystals from forming and damaging tissues is to bathe corals in a rigid metal container filled with a dehydrating solution before plunging them in liquid nitrogen. Whatever water remains in the tissues solidifies so quickly that it cannot crystallize and expand.

Neutrino cartography

A new map of the Milky Way is the first made without using light. Instead, cosmic cartographers used data from a detector in Antarctica and AI to chart nearly massless particles called neutrinos onto the galaxy's plane. The resulting image offered a rough idea of where the first known high-energy neutrinos to originate in the Milky Way were born (SN: 8/12/23, *p.* 13). With some refinement, the approach could pinpoint their birthplace and those of other amped-up ghostly particles.

Every letter counts

This year marked the completion of the pangenome, an effort to catalog every single letter, or building block, in humankind's genetic instruction manual (SN: 6/3/23, *p.* 6). The undertaking involved compiling and comparing nearly all the DNA of 47 people to get the most comprehensive snapshot yet of human genetic diversity. A few months later, researchers added the final piece: the Y chromosome (SN: 10/7/23 & 10/21/23, *p.* 7). The pangenome could shed light on the molecular foundations of fertility, heart disease, Alzheimer's disease and more.

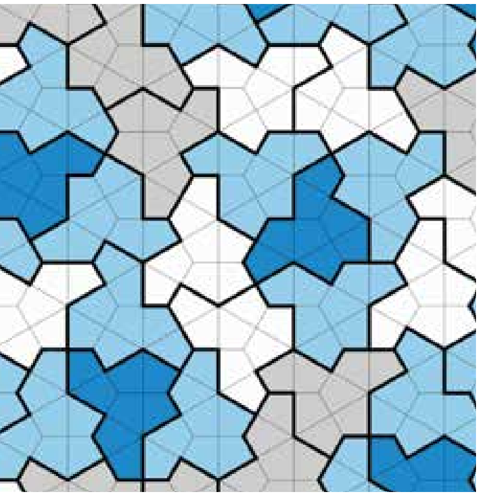
Star eats planet

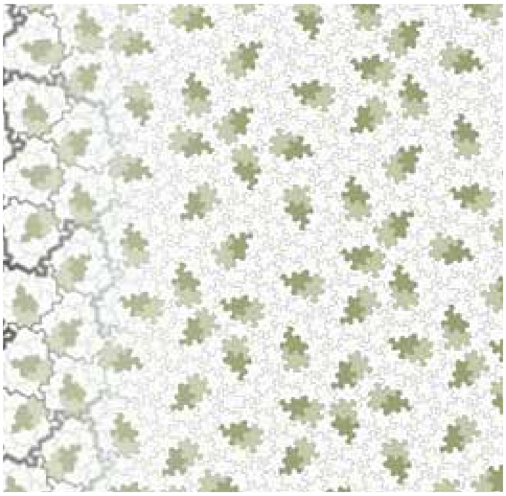
Astronomers have long suspected that stars swallow up planets, but no one had ever caught a star in the act until this year (SN: 6/3/23, *p.* 8). About 10,000 light-years from Earth, the sunlike star engulfed an orbiting planet that was about 10 times as massive as Jupiter. Over several days, the star grew noticeably brighter and burped a bunch of gas, suggesting it engulfed a companion star. But the relatively small amount of energy released tipped off researchers that the star had actually eaten a planet.

Cosmic web shake-up

Glowing threads of gas, galaxies and dark matter provided the first tangible evidence that shock waves permeate the cosmic web, the large-scale structure of the universe (SN: 3/25/23, *p.* 14). Simulations had predicted that colliding threads generate shock waves, which catapult charged particles into the web's magnetic fields and create a faint glow. That aura appeared in data from radio telescopes, confirming the shock waves exist. The glow also provides the first (if indirect) peek at the cosmic web's magnetic fields. — *Cassie Martin*

In March, a group of mathematicians reported the first true "einstein," a shape that can cover an infinite surface in a pattern that never repeats. The 13-sided shape was nicknamed "the hat" (left). Another milestone came in May: the first "vampire einstein," a shape that makes a never-repeating pattern without using its mirror image (right).





BOTH: D. SMITH, J.S. MYERS, C.S. KAPLAN AND C. GOODMAN-STRAUSS (CC BY 4.0)


RISE TO
UNLOCK THE
FUTURE
OF DREAMS
RISE



Wondrous wildlife

Even without a brain, the tiny Caribbean box jellyfish can learn to avoid obstacles.

From jellyfish that can learn to birds that repurpose antiavian architecture, here are dispatches from the animal kingdom that we went wild for in 2023.

Prehistoric pout

Tyrannosaurus rex's menacing grin may have been less toothy than previously thought. Artistic renderings commonly depict the ravenous reptile as lipless, constantly baring its pearly whites. But *T. rex* may actually have had lips that kept rows of pointy teeth covered, similar to Komodo dragons, an analysis of the skulls and teeth of dinosaurs and modern reptiles suggests (SN: 4/22/23, p. 6).

Revenge of the birds

City life can be hostile for birds. Municipalities across the world have put up spikes to prevent birds from roosting — and pooping — on streetlights, buildings and other structures. But some Eurasian magpies (*Pica pica*) and carrion crows (*Corvus corone*) in parts of Europe found a way to stick it to humans. The birds rip up antibird spikes and build nests with them (SN: 9/9/23, p. 4). Magpies may even use the spikes as humans do, to ward off avian pests.

Swashbuckling spiders

Pirates on the high seas would be proud of their landlubbing arachnid counterparts. A species of cannibalistic pirate spider in Costa Rica tricks prey into walking the plank, right into its clutches (SN: 10/7/23 & 10/21/23, p. 11). *Gelanor siquirres* casts a silk thread to intercept that of an unsuspecting orb weaver trying to build a web. When the eight-legged victim scuttles across its own silk thread to secure the other end, the orb weaver finds impending doom rather than harmless vegetation.

Desperate flies, desperate measures

Snow flies (*Chionea* spp.) have a macabre method to survive the frigid mountains and forests they call home. Dozens of flies that researchers subjected to below-zero temperatures self-amputated their limbs, but only when the limbs began to freeze. The flies probably shed the appendages to keep ice crystals from reaching the rest of the body (SN: 7/15/23 & 7/29/23, p. 14).

Self-aware fish

When it comes to brainpower, this fish is no small fry. Not only can the bluestreak cleaner wrasse (*Labroides dimidiatus*) recognize itself in a mirror, the fish can identify a picture of itself out of a lineup (SN: 3/11/23, p. 13). The finding suggests the wrasse forms a mental image of itself — similar to what humans do — and that self-awareness may be more common in the animal kingdom than once thought.

Intelligent jellies

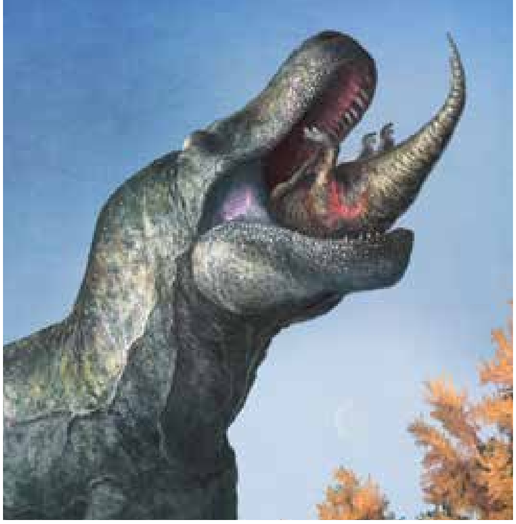
No brain? No problem. The fingernail-sized Caribbean box jellyfish (*Tripedalia cystophora*) uses its clusters of eyes and nerve cells to learn to avoid bumping into things, experiments in an obstacle course suggest (*SN Online*: 9/22/23). In the box jelly's natural habitat, where the creature must swerve to dodge mangrove roots in murky water, it pays to be a good pupil.

Tight-gilled sharks

Regulating body temperature in chilly water is a challenge even for scalloped hammerhead sharks (*Sphyrna lewini*). To stay warm while hunting in the deep ocean, the sharks use a method normally seen in diving mammals: They hold their breath (SN: 6/17/23, p. 10). Keeping gills closed holds in body heat, preventing the predators from becoming fish ice pops.

Big-mouthed snake

This African egg-eating snake redefines what it means to open wide. The Gans' egg-eater (*Dasypeltis gansi*) can open its mouth wider than any other snake relative to its size, lab experiments suggest (SN: 10/7/23 & 10/21/23, p. 36). An egg-eater with a 1-centimeter-wide head could fit a cylinder 5 centimeters across in its mouth. The reptile edges out the previous record holder: the Burmese python (*Python molurus bivittatus*).





Top: *Tyrannosaurus rex* may have had lips that hid its pointy teeth, as depicted here. Bottom: Bluestreak cleaner wrasse can recognize photos of themselves, a possible sign that the fish have self-awareness.

Disaster dogs

The irradiated zone around Ukraine's Chernobyl Nuclear Power Plant might be off-limits for humans, but other animals didn't get the memo. Packs of feral dogs that for years have roamed the area abandoned since 1986 are genetically distinct from canines of similar breeds that live outside the zone (*SN: 4/8/23, p. 15*). The differences probably aren't due to radiation, researchers say. Whether Chernobyl's radioactivity has had any effect on the dogs remains to be seen, but knowing their genetic makeup will help scientists spot potential radiation damage.

Landscaping ants

Many ants are expert navigators, and some use local landmarks to find their way around. But what's an ant to do when the world around them is almost completely flat and featureless? Desert ants (*Cataglyphis fortis*) in Tunisia's salt pans take matters into their own mandibles. Workers build tall mounds over their colonies' nests so wayward foragers can find their way home (*SN: 7/1/23, p. 16*). *— Darren Incorvaia*

FROM TOP: MARK P. WITTON; MARRIO31/ISTOCK/GETTY IMAGES PLUS; NASA/GODDARD SPACE FLIGHT CENTER SCIENTIFIC VISUALIZATION STUDIO

Space mission updates

To the moon, asteroids and beyond, robotic explorers racked up the mileage in 2023. Here's the latest status of space missions that made headlines this year.

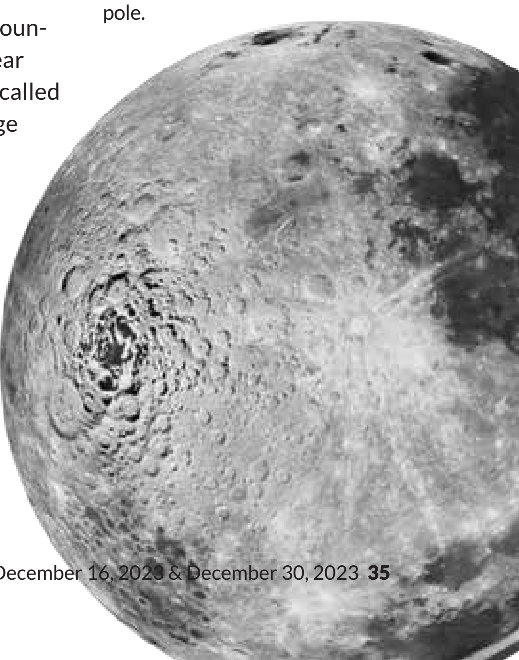
July 1: The European Space Agency launched the Euclid space telescope.
Update: Euclid's aim is to create a 3-D map of the universe to help astronomers better understand dark matter, the mysterious substance that accounts for most matter in the universe, and dark energy, the unknown force that's accelerating the universe's expansion. In November, the telescope showed off what it's capable of when it sent back its first full-color images, dazzling beauty shots of far-off galaxies.

August 23: India became only the fourth country to successfully land on the moon when the Chandrayaan-3 mission's Vikram lander touched down near the lunar south pole, the first spacecraft to do so (*SN: 9/23/23, p. 7*).
Update: High on the mission's to-do list was testing the capabilities of the lander and its rover, named Pragyan, to prep for future lunar missions. The duo also collected measurements, such as the temperature and chemical makeup of the surface. The data could prove useful to space agencies like NASA that intend to send astronauts to the south pole, a tantalizing region that appears to harbor water ice in shadowed craters (*SN: 12/3/22, p. 14*). The mission ended in early September when Vikram and Pragyan entered sleep mode.

September 24: After collecting rock from the asteroid Bennu in October 2020, NASA's OSIRIS-REx spacecraft flew by Earth to drop off its precious cargo (*SN Online: 9/22/23*).
Update: About 250 grams of Bennu safely parachuted to Earth in a protective capsule. So far, scientists have analyzed some bonus material that stuck to the outside of OSIRIS-REx's sample canister before the outer capsule closed. These bits of Bennu mostly consist of water-bearing clay minerals — perhaps the same kind of minerals that made Earth a watery world (*SN: 11/4/23, p. 6*). As of late November, investigations of the bulk of the sample hadn't begun; NASA workers have been unable to remove two of the fasteners that sealed the canister shut. Meanwhile, the mission continues under a new name, OSIRIS-APEX, as the spacecraft travels to the asteroid Apophis with an arrival date of 2029.

November 1: After two years in space, NASA's Lucy spacecraft flew by its first asteroid.
Update: Lucy's goal was to have close encounters with 10 asteroids over a roughly 10-year period. But it turns out that its first target, called Dinkinesh, is actually two asteroids — a large one with a smaller one in orbit around it. Dinkinesh and its tagalong reside in the main asteroid belt, between Mars and Jupiter. But most of Lucy's targets are Trojan asteroids, which share a path around the sun with Jupiter. Studying those space rocks could offer new clues to the origins of the giant planets in our solar system (*SN Online: 10/15/21*). *— Erin Wayman*

India landed a spacecraft near the moon's south pole.



Record breakers

In 2023, researchers made plenty of discoveries for the record books — and the history books. This year's scientific superlatives shed new light on our ancient ancestors, our planet and the animals we share it with.







Top: The extinct whale *Perucetus colossus* may have weighed about twice as much as blue whales. Middle: The Atacama Desert in Chile gets more sunlight than anywhere else on Earth. Bottom: When on hunting trips at sea, northern elephant seals average just two hours of sleep per day.

Oldest wooden structure

Despite what happened to the second little pig's house, wood has long proved a sturdy, reliable construction material — for perhaps as long as half a million years. Carved, interlocking logs uncovered in Zambia date to nearly 480,000 years ago, making them the oldest known wooden structure (*SN Online*: 9/20/23). The structure — possibly a remnant of a walkway, seating area or storage unit — hints that some human relatives may have led a less nomadic lifestyle than previously thought.

Earliest equestrians

The Yamnaya people may have been the world's earliest horseback riders, mounting steeds as far back as 3000 B.C., centuries before the earliest known depictions of horseback riding (*SN: 4/8/23, p. 12*). Yamnaya skeletons unearthed in Romania, Bulgaria and Hungary show telltale signs of horsemanship, including marks on the femur and pelvis that could come from sitting astride and vertebral damage from falling off.

Sunniest place on Earth

Visitors to the Altiplano plateau in Chile's Atacama Desert should be sure to pack sunscreen. This high-altitude region gets hit with an average of 308 watts of sunshine per square meter — the most intense sunlight anywhere on Earth (*SN: 8/26/23, p. 5*). Sometimes, solar radiation exceeds 2,000 watts per square meter, rivaling the amount of sunshine expected to beat down on Venus, which is much closer to the sun than Earth is.

Oldest back hole

A supermassive black hole some 13.2 billion light-years from Earth is the most distant, most ancient supermassive black hole ever observed. The monster dates to when the universe was just 470 million years old, making it about 200 million years older than a record breaker announced in 2021 and 100 million years older than a black hole that claimed the title in July (*SN: 12/18/21 & 1/1/22, p. 29*). Because the newfound black hole boasts about the same heft as its surrounding galaxy, researchers think the black hole could have formed only through the collapse of a massive gas cloud. The finding could help shed light on how the universe's first generation of juggernaut black holes were born.

Snappiest claws

Famously fast adult snapping shrimp have nothing on their young. High-speed video reveals that youngsters can snap their claws up to about 600 kilometers per second per second — an acceleration 20 times as fast as their elders achieve. A 1-month-old shrimp's claw acceleration is on the same order of magnitude as a 9-millimeter bullet blasting out of a gun and is the highest acceleration for a reusable body part underwater (*SN: 4/8/23, p. 5*).

Least sleep among mammals

However sleep-deprived you may be, you're probably still better rested than a northern elephant seal. During monthslong hunting trips at sea, these seals nap less than 20 minutes at a time and average just two hours of total sleep per day (*SN Online*: 4/20/23). That rivals African elephants for the title of mammal that sleeps the least.

Heaviest animal ever

The animal kingdom appears to have a new heavyweight champion. An extinct whale aptly named *Perucetus colossus* might have weighed up to 340 metric tons, about twice as much as the heaviest blue whales, an analysis of fossils found in Peru suggests (*SN: 9/9/23, p. 5*). The mighty mammal is thought to have prowled shallow waters 39 million years ago — but what it could have eaten to maintain its size remains a mystery. — *Maria Temming*

FROM TOP: ALBERTO GENNARI; PAVEL TOCHINSKY/THE IMAGE BANK/GETTY IMAGES; MARK NEWMAN/GETTY IMAGES



Blasts from the past

Christiaan Huygens' telescopes weren't as good as his rivals', even though his lenses (a few shown with a portrait of Huygens) were well made. That may be because the 17th century astronomer needed glasses.

Science occasionally gives us clearer views of the distant past. This year, researchers opened windows into the life and times of ancient Romans, impressionist painters and other towering historical figures.

Vintage essence

What did the ancient Romans smell like? Chemical analyses of a 2,000-year-old perfume bottle from an elite woman's grave suggest a familiar earthy scent: patchouli (SN: 7/1/23, *p.* 14). Patchouli oil permeates modern fragrances, but its use in ancient Rome had been unknown. Perfume extracts that are this old typically dissipate and become lost to history. But the quartz flask was found intact with a bitumen seal that adsorbed some of the perfume molecules, preserving them for millennia.



While this ancient Roman bottle didn't smell like much when unsealed (topper shown above the bottle), chemical analyses revealed its once-heady perfume: patchouli.

Forgery fighter

Infrared and X-ray scans of more than 600 paper bills made by Benjamin Franklin's prolific printing press revealed colorful threads and shiny mineral residues (SN: 8/26/23, *p.* 5). The additives, used to stymie counterfeiters and boost the bills' durability, helped set the standard for paper currency in colonial America, researchers say.

Decoding Beethoven's coda

Ludwig van Beethoven's DNA supports what many historians have suspected: The composer likely died of liver failure (SN: 4/22/23, *p.* 16). Until now, the theory largely rested on reports that Beethoven had been drinking a lot of alcohol shortly before his death in 1827. While reconstructing Beethoven's genome from samples of his hair, researchers discovered he also had a genetic risk for liver disease. The composer also suffered from a hepatitis B infection, the team determined, further compounding his susceptibility to liver damage.

Shrouded in smoke

The Industrial Revolution may have shaped impressionist art — literally. An analysis of more than 100 paintings by artists such as Claude Monet and Joseph Mallord William Turner found that changes in contrast, color and visibility track over time with rising air pollution in London and Paris (SN: 3/25/23, *p.* 4). Particles in smog absorb and scatter light, reducing contrast and making colors whiter. As air pollution worsened throughout the 19th century, impressionist paintings grew paler and hazier just as artists' views of their subjects did.

Huygens' hazy telescopes

Christiaan Huygens, the 17th century Dutch astronomer best known for his studies of Saturn's moons and rings, may have needed glasses. That would explain why the telescopes he designed weren't as sharp as those of his peers, a researcher argues (SN: 4/22/23, *p.* 5). A closer look at Huygens' telescope lenses suggest the scientist was nearsighted. The lenses probably overmagnified his view of the cosmos, making distant objects appear clear to him but fuzzy to others.

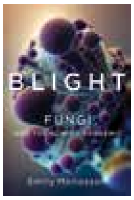
— *Saima S. Iqbal*

FROM TOP: RIJKSMUSEUM BOERHAAVE, LEIDEN; JUAN MANUEL ROMÁN

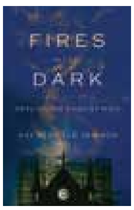
BOOKSHELF

Our favorite books of 2023

Books introducing emerging areas of science, as well as new looks at familiar fields, were among the *Science News* staff's favorite science reads this year. Did we overlook your favorite? Let us know at feedback@sciencenews.org



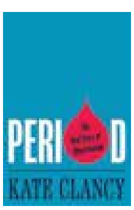
Blight
Emily Monosson
HBO's *The Last of Us* introduced many people to the dangers of fungi. But while a fungus-induced zombie apocalypse is pure fiction, this book warns that a fungal pathogen could spawn the next pandemic (*SN: 8/12/23, p. 28*). *W.W. Norton & Co., $28.95*



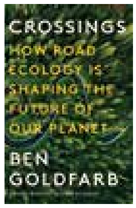
Fires in the Dark
Kay Redfield Jamison
A psychiatrist examines what it takes to be a great healer of mental suffering by exploring the relationship between British poet Siegfried Sassoon, who suffered emotional wounds from combat during World War I, and his physician, W.H.R. Rivers (*SN: 7/1/23, p. 28*). *Knopf, $30*



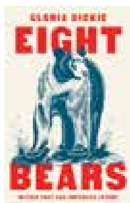
We Are Electric
Sally Adee
This trip through a slice of biology history shows how researchers have tended to ignore the electricity that flows through the body and brain. But that's changing, and studies of the "electrome" could spark medical breakthroughs (*SN: 2/25/23, p. 28*). *Hachette Books, $30*



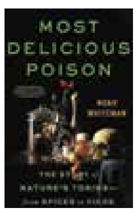
Period
Kate Clancy
Menstruation is such a taboo topic that even the people who experience it once a month or so hold many misconceptions about it. This book draws on history and science to clear up the confusion and destigmatize periods (*SN: 4/8/23, p. 29*). *Princeton Univ., $27.95*



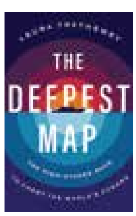
Crossings
Ben Goldfarb
Millions, perhaps even billions, of animals become roadkill every year. This book highlights the work of a passionate group of scientists, known as road ecologists, who study how interventions like wildlife crossings can reduce the toll (*SN: 8/26/23, p. 30*). *W.W. Norton & Co., $30*



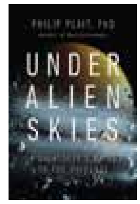
Eight Bears
Gloria Dickie
A reporter travels across three continents to meet the world's eight remaining species of bears, sharing tales of science, folklore and conservation along the way (*SN: 7/15/23 & 7/29/23, p. 33*). *W.W. Norton & Co., $30*



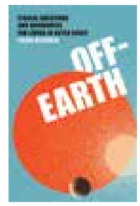
Most Delicious Poison
Noah Whiteman
One creature's poison is another's secret to making a balanced, full-bodied wine. In this blending of science and memoir, an evolutionary biologist chronicles how humans have co-opted nature's toxins to do everything from spicing up food to putting people under anesthesia (*SN: 11/4/23, p. 32*). *Little, Brown Spark, $30*



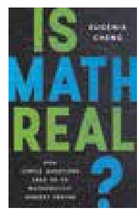
The Deepest Map
Laura Trethewey
This adventure on the high seas follows scientific explorers who are charting the seafloor in exquisite detail. But as with any exploration of uncharted territory, mapping the bottom of the ocean risks spoiling a place largely untouched by humans (*SN: 9/9/23, p. 34*). *Harper Wave, $32*



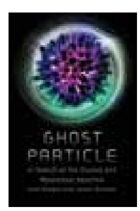
Under Alien Skies
Philip Plait
In this intergalactic travelog, readers are transported to the moon, a comet, Mars, Pluto, exoplanets, a black hole and other celestial worlds to imagine what it would be like to stargaze in these alien places (*SN: 6/17/23, p. 30*). *W.W. Norton & Co., $30*



Off-Earth
Erika Nesvold
As the possibility of humans living in outer space inches closer to reality, an astrophysicist ponders the numerous ethical questions that should be addressed while planning for future settlements on the moon, Mars and beyond (*SN: 3/25/23, p. 28*). *MIT Press, $27.95*

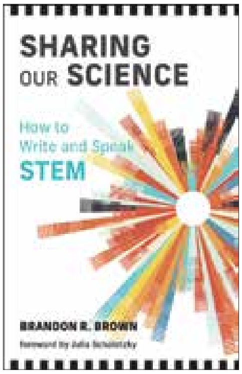


Is Math Real?
Eugenia Cheng
In school, students often learn that the point of math is to solve equations and compute right-or-wrong answers to questions. But exploration is also fundamental to the field. By considering a series of seemingly simple questions, like why 1 + 1 = 2, a mathematician delves into the logical foundations of Western mathematics to reveal the discipline's true nature (*SN: 10/7/23 & 10/21/23, p. 32*). *Basic Books, $30*

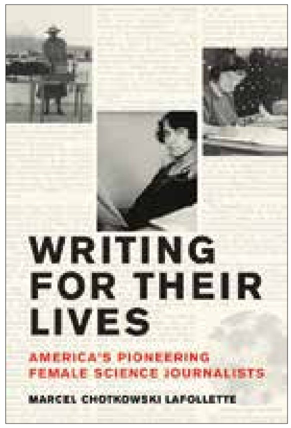


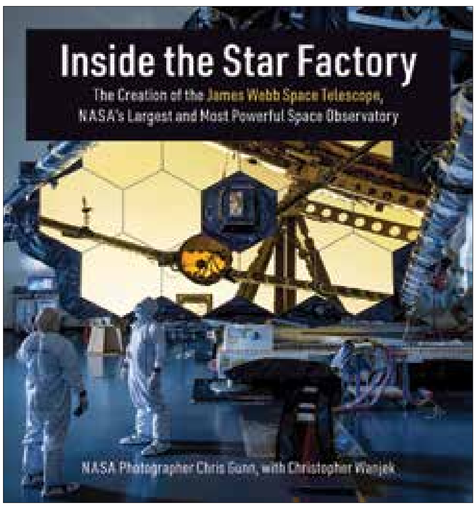
Ghost Particle
Alan Chodos and James Riordon
Written by a physicist and a *Science News* writer, this comprehensive story of neutrinos is the perfect primer for anyone curious about how the elusive subatomic particles were discovered, why they matter to physics, and what mysteries are still waiting to be solved (*SN: 3/11/23, p. 28*). *MIT Press, $32.95*

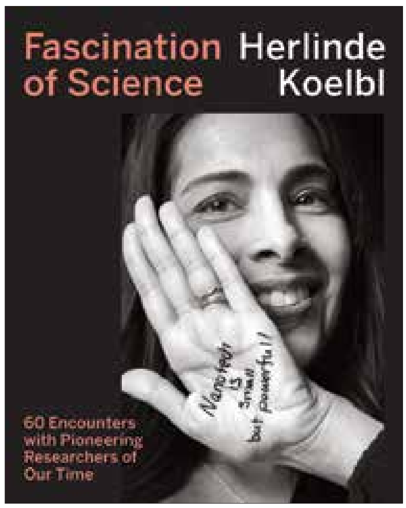
Books for the *Science Fanatics*

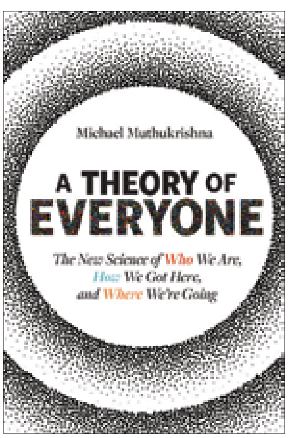


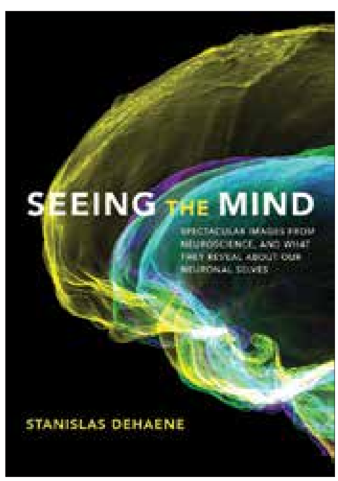












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TOP MOMENTS

2023 was another extraordinary year for Society for Science, publisher of Science News. We rewarded many of the top young STEM innovators in our country, reported breakthrough research and supported educators. Here are some of our favorite moments.



Thermo Fisher Scientific Junior Innovators Challenge
Shanya Gill won the top $25,000 award at the inaugural Thermo Fisher Scientific Junior Innovators Challenge for creating a new type of fire detector.



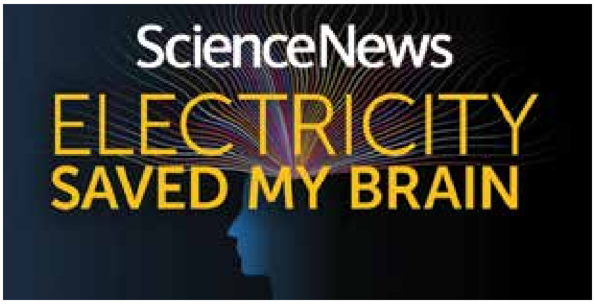
STEM Action Grant Program
The Society awarded $254,000 in STEM Action Grants to 53 dynamic, community-centric STEM organizations in 24 states and Washington, D.C.

Invention Education Fellow
The Society named Yolanda Payne its first Invention Education Fellow, who will increase invention education awareness.



Advocate Program
The Society named 100 educators to its Advocate Program, which seeks to engage more students in STEM competitions and science fairs. To date, Advocates have supported over 6,000 students and over 4,400 students who have successfully competed in at least one science research competition.





Serial Newsletter
Science News published a multipart series, first shared as a serial newsletter, exploring the use of deep brain simulation to treat severe depression.



AAAS Kavli Science Journalism Awards
In its 20th year, Science News Explores swept the AAAS Kavli Science Journalism Awards, bringing home the Gold and Silver awards in the "Children's Science News" category.



Regeneron Science Talent Search
Neel Moudgal won first place and $250,000 in the Regeneron Science Talent Search for creating a computer model that can rapidly and reliably predict the structure of RNA molecules using only easily accessible data.



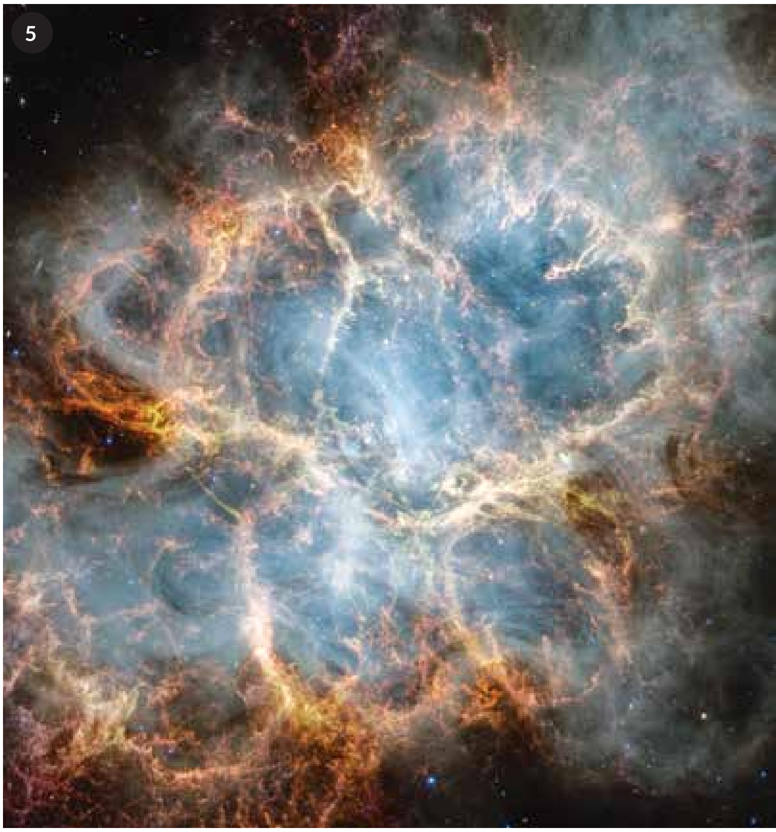
Technology Enhances the Arts
The Society created a new Regeneron International Science and Engineering Fair category, Technology Enhances the Arts, that highlights the growing role that technology plays in the arts.

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Postcards from the James Webb telescope

This year, the James Webb Space Telescope celebrated its first full year of operation, during which it returned a treasure trove of images. And it's just getting started.

Since it first began sending pictures back home in July 2022, JWST has peered deeper in space and farther back in time than any previous telescope could manage (SN: 8/13/22, *p.* 30). Hundreds of scientific papers have already been published based on JWST images, barely a year and a half into the telescope's planned 10-year lifetime.

But JWST may end up having much more than a decade to study the cosmos. Thanks to a perfect launch, the mission was left with far more fuel to control the telescope than expected, astronomer Jane Rigby of NASA's Goddard Space Flight Center in Greenbelt, Md., said in September at the First Year of JWST Science Conference in Baltimore. "Now we have more than 25 years of propellant."

If the first 18 months of JWST science are any indication, the telescope could be ushering in a decades-long golden age for astronomy. Here's just a few of the things JWST showed us in 2023. —*James R. Riordon*

1 HH 211 Glowing jets of gas, dubbed HH 211, bracket what researchers have long thought was a lone, young star (not visible). Ripples along the center of the outflows hint that the star may in fact be twins, a pair of young stars orbiting one another.

2 Uranus A view over the north pole of the blue world reveals clouds (small bright spots), rings and a large misty-looking polar cap, whose origin is unknown. The cap seems to form only as Uranus, which is tipped on its side, exposes the pole to the sun.

3 Rho Ophiuchi Young stars are scattered throughout this stellar nursery, which at 390 light-years away, is the closest one to Earth. The youngest are ensconced in dark regions, announcing themselves with jets of hydrogen (red along top and bottom left). Around some of those stars, JWST spied dusty disks, where planets could grow.

4 Orion Bar In this part of the Orion Nebula, molecular clouds envelope newborn stars. Around one star (not visible), JWST detected a carbon and hydrogen compound that suggests chemicals needed for life can survive the radiation of a stellar nursery. In this false-color image, the reddish-brown clouds are denser than the blue.

5 Crab Nebula Magnetic fields from a neutron star left behind after a supernova — visible from Earth in the year 1054 — whip up electrons to near light speed, causing them to emit light in a pattern resembling a smoky cloud (white) that pervades the nebula.

OPPOSITE PAGE, CLOCKWISE FROM TOP LEFT: WEBB/ESA, NASA, CSA, TOM RAY/DUBLIN; NASA, ESA, CSA, STSCI, JOSEPH DEPASQUALE/STSCI; NASA, ESA, CSA, STSCI, TEA TEMIM/PRINCETON UNIV.; WEBB/ESA, NASA, CSA, M. ZAMANI/WEBB/ESA, PDRS4ALL ERS TEAM; THIS PAGE: NASA, ESA, CSA, STSCI, KLAUS PONTOPPIDAN/STSCI, ALYSSA PAGAN/STSCI

Online favorites of 2023

Science News drew over 21 million visitors to our website this year. Here's a look back at the most-read and most-watched stories of 2023.

SOCIAL MEDIA

Top TikTok

A video about Beethoven's hair was our most-viewed TikTok posted this year. In the video, civic science fellow Martina Efeyini (shown below) talks about what DNA extracted from the composer's locks reveals about how he may have died (see Page 37). Watch the video at **bit.ly/SN_TikTok23**



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Top news stories

1 Fungi that cause serious lung infections are now found throughout the U.S.

An analysis of Medicare records from 2007 through 2016 reveals that *Histoplasma*, *Coccidioides* and *Blastomyces* fungi have become more widespread in the United States. The fungi, which cause serious lung infections, were once thought to be confined to certain regions of the country (*SN: 1/14/23, p. 32*).

2 A new look at Ötzi the Iceman's DNA reveals new ancestry and other surprises

Ötzi the Iceman's ancestors may have been Neolithic farmers, a new genetic analysis indicates. Previous studies suggested that the roughly 5,300-year-old frozen mummy had ancestors from the Pontic-Caspian steppe. Ötzi also had male-pattern baldness and darker skin than previously thought (*SN: 9/23/23, p. 5*).

3 Mathematicians have finally discovered an elusive 'einstein' tile

A newfound 13-sided shape dubbed the hat is the first true "einstein," a tile that forms a pattern that can cover an infinite plane but does not repeat. Mathematicians had been searching for an einstein for half a century (see Page 32).

4 Earth's inner core may be reversing its rotation

Earth's heart may have temporarily stopped spinning relative to the mantle and crust in 2009. Now, the inner core may be reversing its spin as part of a cycle that happens every few decades (see Page 24).

5 Astronomers spotted shock waves shaking the web of the universe for the first time

Shock waves ripple along the magnetic fields that permeate the cosmic web — the tangle of galaxies, gas and dark matter that fills the universe. Studying these shock waves, which were revealed by hundreds of thousands of radio satellite images, could help astronomers better understand those mysterious magnetic fields (see Page 32).

Top long reads

1 A massive cavern beneath a West Antarctic glacier is teeming with life

A vast, water-filled "cathedral" roughly 500 meters beneath the Kamb Ice Stream, a glacier in West Antarctica, bustles with marine organisms. The cavern provides a window into the continent's warmer ancient past (*SN: 4/22/23, p. 18*).

2 Why scientists are expanding the definition of loneliness

Social scientists now increasingly recognize that loneliness results not just from isolation from people, but also from animals, places, routines, rituals and more. That view may lead to new ways to manage the feeling, which is becoming a public health concern in the United States (*SN: 11/4/23, p. 24*).

3 How brain implants are treating depression

Deep brain stimulation, a technology that pulses electricity deep into the brain, may be the only hope for relief for some patients with severe depression. In this series, the stories of Jon Nelson and three other patients undergoing the experimental treatment offer an intimate look at how it has changed their lives (*SN: 9/23/23, p. 16*).

4 A chemical imbalance doesn't explain depression. So what does?

Depression is often blamed on a "chemical imbalance" in the brain. In reality, despite decades of sophisticated research, scientists still don't have a great explanation of what depression is or what causes it (*SN: 2/11/23, p. 18*).

5 How one device could help transform our power grid

Coal-fired power plants across the United States are shutting down as society shifts toward clean energy sources. A smooth transition to renewables could depend in large part on grid-forming inverters, devices that hook up solar and wind farms to the existing power grid and stabilize the system (*SN: 8/26/23, p. 22*).

